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LAKE POLLUTION PREVENTION AND RESTORATION USING ELECTROFLOTATION AND FILTRATION

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ABSTRACT

This publication identifies lake eutrophication, its biochemical process, causes, effects, prevention, lake restoration, available technologies (electroflotation, dissolved air flotation and filtration), etc. Two continuous pilot plant studies were conducted: (a) treatment of septic tank effluent along lake shoreline by electroflotation-filtration (EFF) and drainfield for lake pollution prevention; and (b) treatment of Stockbridge Bowl water by EFF for lake restoration. The new technologies were jointly developed by the Lenox Institute of Water Technology (LIWT) and Krofta Engineering Corporation (KEC). For lake pollution prevention, a septic tank effluent was successfully treated to meet the NPDES effluent discharge permit requirements. For lake restoration, Stockbridge Bowl water was successfully treated in terms of high % removal of phosphate-P (100%), TSS (100%), COD (71%), color (95%), turbidity (90%), aluminum (58%), and algae or particle counts (99.7%), etc. The authors also discuss other lake pollution prevention and restoration methodologies: such as property awareness, on-site septic effluent clarification, in-lake restoration (aeration, chemical precipitation, etc.), barge mounted flotation treatment plants, algae harvesting for energy production, and lake acid rain reversal etc. Although only the LIWT-KEC technologies were used for the feasibility studies, another manufacturers' equivalent process equipment is expected to produce similar performance data, if their process equipment is optimized. For lake applications, the equipment foot-print must be small and the overall costs must be affordable. Continuous pilot plant demonstration of any manufacturer's process equipment is highly recommended. This publication is one of many professional memoirs being written by the authors.

KEYWORDS:

memoir, Lenox Institute of Water Technology, Krofta Engineering Corporation, lake water pollution, limnology, eutrophication, nutrients, nitrogen, phosphorus, aquatic plants, algae, water pollution control, humic substances, pollution prevention, lake restoration, electroflotation, dissolved air flotation, filtration, point source pollution, non-point source pollution, watershed protection, septic tank effluent treatment, algae, acid rain reversal, neutralization, Stockbridge Bowl, Berkshire, Massachusetts

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NOMENCLATURE

ANC: Acid neutralizing capacity

COD: Chemical oxygen demand

DAF: Dissolved air flotation

DGF: Dissolved gas flotation

DO: Dissolved oxygen

EF: Electroflotation

EFF: Electroflotation-filtration

gpd: Gallons per day

KEC: Krofta Engineering Corporation (KEC)

LIWT: Lenox Institute of Water Technology

NOx : Nitrogen oxides

NPDES: National Pollutant Discharge Elimination System

POTW: Publicly Owned Treatment System

SBA: Stockbridge Bowl Association

SO_2 : Sulfur dioxide

TSS: Total suspended solids

USEPA: United States Environmental Protection Agency

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1. INTRODUCTION

1.1. Eutrophication Process and Environmental Problems

This publication briefly introduces limnology which is the study of the biological, chemical, and physical features of inland fresh waters in lakes, ponds, rivers, springs, streams, wetlands and of other bodies of semi-fresh water. Limnology is different from oceanography because the latter (oceanography) is the study of the ocean including its currents, waves, tides pollution, ocean lives, the geology of the sea floor, the various physical, chemical and biochemical properties of ocean water and sea floor, and sea water intrusion into the ground water body. There are some inland water body containing saline water, however.

Lakes are valuable resources which offer fishing, boating and swimming' opportunities as well as supplies of water and a setting for seasonal and year round residences. Lake aging threatens these uses. Under normal circumstances, lakes age very slowly moving from a condition characterized by few aquatic plants and animals, high oxygen levels and very clear water to a condition where there is a great variety of aquatic plants and animals, oxygen levels drop in late summer and water is less clear. The development of lake watersheds, the area which drains into a lake, for residential and commercial purposes and the nutrient contributions from such development can drastically accelerate the process of lake aging.

Briefly speaking eutrophication is a plant growth process due to the nutrient supply. Specifically eutrophication is an environmental process that (a) involves the gradual increase in the concentration of phosphorus, nitrogen, and other plant nutrients in an aging aquatic ecosystem; (b) results an excessive richness of nutrients in a lake, or pond, or river bend frequently due to decay of natural humic substances, storm runoff from the land, point-source pollution (such as septic tank effluent), non-point source pollution (such as agricultural wastewater discharges) , etc. and (c) causes a dense growth of plant life and death of aquatic animal life from lack of oxygen.

Nutrients and the growth of most aquatic plants, such as algae, are not harmful to people, but to the lake itself. Although both nitrogen and phosphorus are the nutrients that support the aquatic plant growth, such as the algae growth, the National Eutrophication Survey of the United States Environmental Protection Agency (USEPA) has determined that phosphorus is the limiting nutrient in 57% of all US northeastern lakes surveyed. The limiting or critical nutrient of the other northeastern lakes surveyed remains questionable. In addition, limnology research has determined that phosphorus is usually the nutrient which is in shortest supply and therefore limits productivity in northeastern lakes.

Although algae growth is an environmental problem, algae may be harvested for possible production of energy or other types of reuse.

1.2 Objectives of the Research

The objectives of this research were: (a) to identify and discuss the environmental problems of lake eutrophication; (b) to determine the feasibility of using electroflotation (EF) process for removing phosphate and algae from a polluted lake water; (c) to demonstrate the feasibility of treating the septic tank effluents surrounding the lake for pollution prevention; and (d) to determine the feasibility of using dissolved air flotation (DAF) for algae harvesting, and reuse.

1.3 Summary

This publication identifies lake eutrophication, its biochemical process, causes, effects, prevention, lake restoration, available technologies (electroflotation, dissolved air flotation and filtration), etc.

Two continuous pilot plant studies were conducted: (a) treatment of septic tank effluent along lake shoreline by electroflotation-filtration (EFF) and drainfield for lake pollution prevention; and (b) treatment of Stockbridge Bowl water by EFF for lake restoration. The new technologies were jointly developed by the Lenox Institute of Water Technology (LIWT) and Krofta Engineering Corporation (KEC).

For lake pollution prevention, a septic tank effluent was successfully treated to meet the NPDES effluent discharge permit requirements.

For lake restoration, Stockbridge Bowl water was successfully treated in terms of high % removal of phosphate-P (100%), TSS (100%), COD (71%), color (95%), turbidity (90%), aluminum (58%), and algae or particle counts (99.7%), etc.

The authors also discuss other lake pollution prevention and restoration methodologies: such as property awareness, on-site septic effluent clarification, in-lake restoration (aeration, chemical precipitation, etc.), barge mounted flotation treatment plants, algae harvesting for energy production, and lake acid rain reversal etc.

Although only the LIWT-KEC technologies were used for the feasibility studies, another manufacturers' equivalent process equipment is expected to produce similar performance data, if their process equipment is optimized. For lake applications, the equipment foot-print must be small and the overall costs must be affordable. Continuous pilot plant demonstration of any manufacturer's process equipment is highly recommended. This publication is one of many professional memoirs being written by the authors.

2. POINT AND NON-POINT PHOSPHORUS SOURCES OF SURFACE WATER POLLUTION

"Surface waters" means: (a) All waters that are currently used, were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters that are subject to the ebb and flow of the tide; (b) All interstate waters, including interstate wetlands; (c) All other waters such as intrastate lakes, rivers, streams (including intermittent streams), mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds and the use, degradation, or destruction of which would affect or could affect interstate or foreign commerce including any such waters: (c1) That are or could be used by interstate or foreign travelers for recreational or other purposes; (c2). From which fish or shellfish are or could be taken and sold in interstate or foreign commerce; or (c3) That are used or could be used for industrial purposes by industries in interstate commerce; (d) All impoundments of waters otherwise defined as surface waters under this definition; (e) Tributaries of waters; (f) The territorial sea; and (g) Wetlands adjacent to waters, other than water that are themselves wetlands.

So both lake water and wetland water are of surface water. Lake water pollution is one of surface water pollutions.

Phosphorus may enter lakes from pipes or other conduits in which case the source is called a "point source" or wash off land or structures in which case it is referred to as a "non-point source". Technically "point source discharge" means any discernible, confined, and discrete conveyance including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel, or other floating craft from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture or agricultural storm water run-off.

Most lakes have few point sources discharges. There are many non-point sources of phosphorus which may pertain to a lake including erosion, septic systems, landfills, motor vehicles, atmospheric fallout, waterfowl and livestock. If there is unsewered residential development near the lake and/or tributary surface waters, septic systems could be considered as a significant source of phosphorus. If there are any roads in the basin, motor vehicles should be considered. If there are landfills within the watershed, whether currently in use or closed, they should be considered. If there is any kind of livestock: cows, chickens, horses, sheep, pigs, etc., they should be considered. Other non-point sources could be discovered and, if so, quantify it by the best method available. The most important sources are "natural" runoff, erosion, septic system inputs, groundwater and regeneration within the lake itself.

3. WATERSHED PROTECTION

Lake eutrophication is a natural process which can be greatly accelerated by activities within a lake drainage basin. Much of the precipitation that falls within the lake's drainage basin passes through the lake, ultimately affecting the lake's water quality. The size of the watershed and uses made of land within a watershed determines phosphorus loading to a lake. The size of the lake and it's hydrogeologic characteristics determine the tolerance of a lake to phosphorus to a large extent. [1]

"Wetlands" means those areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

The presence of wetlands in a lake watershed, particularly when wetlands are contiguous with tributary surface waters, can be a very significant factor in reducing available phosphorus loadings in tributaries during the low flow period of the summer growing season. Wetlands can also impart a "tea coloration" from humic substances which reduces light penetration and, hence, weed abundance. Removal of the natural vegetative cover, the destruction of wetlands, disturbing the land surface, installing septic systems near the lake, grazing livestock, growing crops, driving motor vehicles, disposing of solid waste and locating discharging industries within the lake's watershed are some of the activities which cause artificial enrichment of lake waters. The occurrence of heavy rain storms, flash flooding and rapid ice melt contribute heavily to nutrient enrichment of which there is very little one can do to prevent such occurrences. [2]

A lake's water quality is determined to a large extent by what happens in the watershed. Any types of point source discharges (such as sewage), or non-point source discharges (such as over-flooded agricultural waste stabilization ponds or lagoons), must be prevented from being directly discharged into the watershed without proper treatment. "Sewage" includes all water carried and non-water carried human excrement, kitchen, laundry, shower, bath, or lavatory wastes separately or together with such underground, surface, storm, and other water and liquid industrial wastes as may be present from residences, buildings, vehicles, industrial establishments, or other places.

4. LAKE WATER POLLUTION

4.1 Causes

The nutritional condition of a lake is referred to as it's trophic status. An oligotrophic lake is low in nutrients and has very clear water. An eutrophic lake is highly enriched, has generally poor transparency during the summer months and may have an oxygen deficiency near the bottom sufficient to cause cold water fish life to perish. An immediately visible characteristic of an eutrophic lake is early to mid-summer algal blooms and/or dense beds of aquatic plants. Algal blooms may appear as green . slime on rocks or beach or green floating mats or may simply turn surface waters green. A mesotrophic lake is somewhere between the two with generally less oxygen depletion near the bottom. [1]

Over nourishment is the cause of the eutrophication problem. Many nutrients are necessary for plant growth, but phosphorus, nitrogen and carbon are most likely to be limiting. Phosphorus is usually easier to control than nitrogen and carbon which have a gas phase in the natural cycle.

4.2 Decomposition

Lakes are very efficient solar collectors. The way lake waters warm up in the spring and early summer is by absorbing the energy contained in light which penetrates the lake surface turning it into sensible heat. Because light enters from the top of a lake, the water column heats from the top down. Layers of water at different temperatures can have very different densities and, therefore, these layers can float on one another. Density differences determine how easily the water column is mixed by the action of wind and mixing by motor boats. Density difference between water layers at 29 ^{o}C and 30 ^{o}C is 40 times greater than water layers at 4 ^{o}C and 5 ^{o}C . Because of these density differences caused by warming of surface waters, light energy causes three distinct layers to form in deep lakes.

The warm, generally well mixed, surface water layer is called the epilimnion. The thickness of this layer will depend upon the depth of light penetration as a result of water clarity. Also, because of the greater density difference at higher temperatures, some lakes undergo periods of time when this . warm water layer itself stratifies into layers. However, these episodes of stratification within the epilimnion generally last less than two weeks and are usually missed by sampling programs. Below the warm epilimnion is a layer of water characterized by rapidly decreasing temperature (and hence, increasing density). This layer called, the metalimnion, contains very steep density boundaries, and acts as a transition zone between the warm surface layer and the cold, dark bottom layer. Below this middle layer (metalimnion) is a uniformly cold, dark bottom layer called the hypolimnion. Algal blooms tend to' occur in the warm, illuminated epilimnion and occasionally occur within the metalmnion.

4.3 Metabolism

Organic material which comes from the watershed, or which is produced within the lake, settles through the water column and tends to accumulate on the bottom of the lake. This organic material is decomposed, primarily by bacteria, with a resulting loss of oxygen from the bottom of the lake. Decomposition does not stop with the loss of oxygen, and other chemicals are used by bacteria to break organic material down and release it as carbon dioxide and water. The first process (which uses oxygen) occurs as long as oxygen is present. Once the water is devoid of oxygen, one of the first chemicals used in its place is nitrate. The nitrate is reduced to nitrite, ammonia and often times all the way to gaseous nitrogen which may leave the lake. This process is called denitrification. [3]

In many lakes decomposition proceeds beyond the use of nitrate once the supply is exhausted. After nitrate, iron, manganese and- sulfur are the next chemicals used in this anaerobic decomposition process. In general, it is more healthy for a lake to use nitrate in anaerobic decomposition than to proceed to the other chemicals, particularly sulfur. When sulfur is used, hydrogen sulfide' is produced and accumulates in the bottom layer of the lake. Hydrogen sulfide is highly toxic (more so even than cyanide) and can be damaging in certain circumstances. In addition, once decomposition proceeds past the use of nitrate, more phosphorus will be released from the bottom mud due to a decrease in the absorption capacity of sediments.

5. LAKE RESTORATION

5.1 Property Owner Awareness

Legally speaking "owner" means the government or any of its political subdivisions, including sanitary districts, sanitation district commissions and authorities, or any individual, any group of individuals acting individually or as a group, or any public or private institution, corporation, company, partnership, firm, or association that owns or proposes to own a sewerage system or treatment works.

A strategy which could be implemented immediately is a property owner (including both homeowner and institutional owner) awareness program. Such a program would advocate careful selection of the types of detergents or chemicals used within the watershed, maintenance of septic systems, proper application of fertilizers and other property owner actions which would alleviate eutrophication contributors.

A voluntary phosphate detergent ban is a logical first step which would increase public involvement and would significantly reduce the annual phosphorus load (on the order of perhaps, 10 to 20 %). Commercial property owners should prevent the release of phosphorus-containing fertilizers into the lake water.

5.2. On-Site Septic Effluent Clarification for Lake Pollution Prevention

"Conventional onsite sewage system" is a treatment works consisting of one or more septic tanks with gravity, pumped, or siphoned conveyance to a gravity distributed subsurface drainfield. A properly designed and operated conventional onsite sewage system, if it is far away from lake or water well, will not create any water pollution problem. If the onsite sewage system fails or is too close to the lake or well, then remediation is needed.

A "failing onsite sewage disposal system" means an onsite sewage disposal system where the presence of raw or partially treated sewage on the ground's surface or in adjacent ditches or waterways or exposure to insects, animals, or humans is prima facie evidence of a system failure. Pollution of the groundwater or backup of sewage into plumbing fixtures may also indicate system failure. In case the failing onsite sewage disposal system is beyond repair or too closed to a lake or a well, then an alternative treatment system can be considered.

There are two kinds of alternative treatment systems: (a) alternative onsite sewage treatment system; and (b) alternative discharging sewage treatment system.

An "alternative onsite sewage treatment system" is a treatment works that is not a conventional onsite sewage system and does not result in a point source discharge.

An "alternative discharging sewage treatment system" or "discharging system" is any device or system that results in a point source discharge of treated sewage for which the government may issue a permit authorizing construction and operation when such system is regulated by the government under a discharge permit issued for an individual single family dwelling or an institute with flows usually less than or equal to 1,000 gallons per day on a monthly average.

Liquid septic tank effluent, which is normally fed to a drainfield (or leaching) system, could easily be treated with a small electroflotation unit, which was developed by the Lenox Institute of Water Technology (LIWT), and manufactured and distributed by international companies associated with Krofta Engineering Corporation KEC).

Section 6 of this chapter presents the results of a feasibility study in which an electroflotation-filtration (EFF) process unit (Krofta Model SAF-0.5; 0.5 ft. diameter) successfully treated a septic tank effluent for removal of phosphorus, nitrogen, chemical oxygen demand (COD), total suspended solids (TSS), turbidity and color. If an EFF process unit is installed, in the event that the leaching field is not functioning properly, as during early spring, due to a high water table, any septic tank effluent not properly leaching through the soil would pose no problems to humans, animals or the environment, as this wastewater would be fully treated by EFF and void of any chemicals that would aid lake eutrophication. As a last step in the EFF clarification stage, pH is easily corrected so as not to lend itself as a source to the rapidly growing problem of acidic lakes.

It is known that sulfur dioxide (SO_2) and nitrogen oxides (NOx) from air pollution will cause acid rain, in term, cause acidic lake. Chemical reaction of nitrogen oxides with lake will produce nitrate ions (NO_3^-) which can be another input of nutrient to the lake water. [4] The feasibility of using dissolved air flotation and filtration for lake restoration has been demonstrated [4], [5], [6], [7], [8], [9]

It is understood that there will be other "alternative onsite sewage treatment system" or alternative discharging sewage treatment system" commercially available, although the authors only introduce EFF in this book chapter.

5.3. In-Lake Restoration

A third strategy is "in-lake restoration", which is in experimental stages in other lakes. At present, some form of "hypolimnetic treatment" may be of benefit. Such a treatment may involve limited aeration, selective withdrawal-treatment-return, chemical precipitation of phosphorus or some similar method. In addition to a physical or chemical treatment of the bottom layer, the potential for improving water quality by manipulating fish populations in the correct manner is also an attractive strategy.

Other lake restoration methods currently under consideration by the Commonwealth of Massachusetts and the local government and the Stockbridge Bowl Association (SBA) are: (a) using a mechanical harvester to cut weed stems, several feet below the surface, to a level where they wouldn't interfere with recreational use of the lake; (b) a drawdown dredging, and hydro-raking; (c) instead of a drawdown, using fluridone, a narrow-spectrum herbicide that specifically targets milfoil. [12]

5.4 Barge Mounted Package Plants

Because non-point sources contribute a significant amount of phosphorus to the lake basin, an ongoing treatment process should be initiated to continually remove this incoming phosphorus. A water treatment package plant mounted on a floating barge would reduce phosphate to the extent of 90 - 95 %. In addition, algae, dissolved and undissolved particulate matter would be removed which would lead to a more pristine condition of low nutrient content and greatly increased clarity.

Effective removal of phosphate and algae, which complex phosphorus in the cellular structure via a LIWT-KEC developed electroflotation-filtration (EFF) technology is reported in Section 7 of this chapter.

5.5 International Dialogues and Call for More Research

Lake pollution (including both eutrophication and acdification) is recognized as an international environmental problem by both industrial and developing countries. Today thousands of research projects have been funded and applied to the problem site. This can only be brought about by the organized efforts of a lake restoration organization that has a single goal: improving and preserving lake water quality and fishery habitat. This group must be non-profit to attract funding. This group, Lenox Institute of Water Technology (LIWT), had obtained funding for several diagnostic/feasibility studies under the Massachusetts Clean Lakes Program with local match grants from municipal and private contributions.

The following three sections summarize some LIWT research findings:

(a) Section 6: Feasibility Study of Treating Septic Tank Effluent by Electroflotation-Filtration (EFF) and Drainfield for Lake Pollution Prevention; and (b) Section 7: Feasibility Study of Treating Stockbridge Bowl Water by Electroflotation-Filtration for Lake Restoration.

6. FEASIBILITY STUDY OF TREATING SEPTIC TANK EFFLUENT BY ELECTROFLOTATION-FILTRATION (EFF) AND DRAINFIELD FOR LAKE POLLUTION PREVENTION

6.1 Electroflotation-Filtration Process, Equipment and Operational Procedure

EF is one of many flotation processes, such as (a) plain gravity flotation; (b) dissolved air flotation; (c) dispersed air flotation or induced air flotation; (d) vacuum flotaiton; (e) electroflotation; and biological flotation, as indicated by Table 1.

Electrolytic flotation is same as Electroflotation (EF). The combination of an electroflotation clarifier and a sand filter becomes a small package plant known as electroflotation-filtration (EFF). Table 1 briefly introduces each flotation process and its principles.

Table 1. Types of flotation processes

1.	Plain gravity flotation	
	Example:	API Oil–water separator
		Wax water separator
2.	Dissolved air flotation (DAF)	
	Example:	Full flow pressurization system
		Partial flow pressurization system
		Recycle flow pressurization system
	Flow pattern:	Laminar flow, Fine air bubbles
	Air Addition:	1% of liquid influent flow
3.	Dispersed air flotation (or induced air flotation)	
	Example:	Deinking flotation
		Foam separation
		Gas stripping
		Aeration/oxidation
		Ore flotation
	Flow pattern:	Turbulent flow, large air bubbles
	Air addition:	400% of liquid influent flow
4.	Vaccum flotation	
	Example:	Scum vacuum flotation
5.	Electrolytic flotation (or electroflotation)	
	Example:	Sacrificing electrode system
		Non-sacrificing electrode system
	Flow pattern:	Laminar flow, fine bubbles
	Gas production:	
		Anode: $2H_2O \longrightarrow 4H^+ + O_2 + 4e^-$
		Cathode: $4e^- + 4H_2O \longrightarrow 2H_2 + 4OH^-$
		$2H_2O \longrightarrow 2H_2 + O_2$
6.	Biological flotation	
	Example:	Activated sludge thickening under denitrification condition
	Flow pattern:	Laminar flow and fine bubbles
	Gas production:	
		$6NO_3^- + 2CH_3OH \longrightarrow 6NO_2^- + 2CO_2 + 4H_2O$
		$6NO_2^- + 3CH_3OH \longrightarrow 3N_2 + 3CO_2 + 3H_2O + 6OH^-$
		$6NO_3^- + 5CH_3OH \longrightarrow 5CO_2 + 3N_2 + 7H_2O + 6OH^-$

Specifically electroflotation (EF) is a process involving the generation of hydrogen and oxygen bubbles in a dilute electrolytic aqueous solution by passing a direct current between two electrodes (a) anode and (b) cathode. Anode reaction generates oxygen bubbles and hydrogen ions; while cathode reaction generates hydrogen bubbles and hydroxide ions. [5]

Either aluminum or steel sacrificial electrodes can be employed for generating the gas bubbles as well as coagulants at the same time. Non-sacrificial electrodes are employed for generating the gas bubbles only, and can be mode of titanium (as the carrier material) and lead dioxide (as the coating material).

Electrical power is supplied to the electrodes at a low voltage potential of 5 to 20 volts DC by means of a transformer rectifier. Small bubbles in the range of 20-50 microns are produced under laminar hydraulic flow conditions feasible for flotation separation of fragile flocs from water in a small system. The floats on the water surface are the impurities/pollutants removed from water. The clarified water is discharged from the flotation clarifier's bottom.

There can be unexpected advantages and disadvantages when electroflotation is employed. For instance, chlorine bubbles may be generated as a water disinfectant if the water contains significant amount of chloride ions. Certain unexpected gas bubbles may be generated and may be undesirable. The readers are referred to the literature for additional technical information concerning electroflotation [10] and filtration [11]

Figure 1 is the photo of a small electroflotation-filtration (EFF) process system (Krofta Model SAF 0.5; diameter = 0.5 ft) which was jointly developed by the Lenox Institute of Water Technology (LIWT) and Krofta Engineering Corporation (KEC) and specifically designed for single family living near lake shore.

Figure 2A is a flow diagram of an EFF set up for treatment of a single family's septic tank effluent. Figure 2B explains the operational procedures of two process cycles: (a) electroflotation-filtration cycle, or simply filter cycle; and (b) backwash cycle.

Figure 1. An electroflotation-filtration package plant (Krofta Model SAF-0.5; diameter = 0.5 ft)

Figure 2A. Flow diagram and structure of an electroflotation-filtration unit. (Krofta Model SAF-0.5; diameter = 0.5 ft)

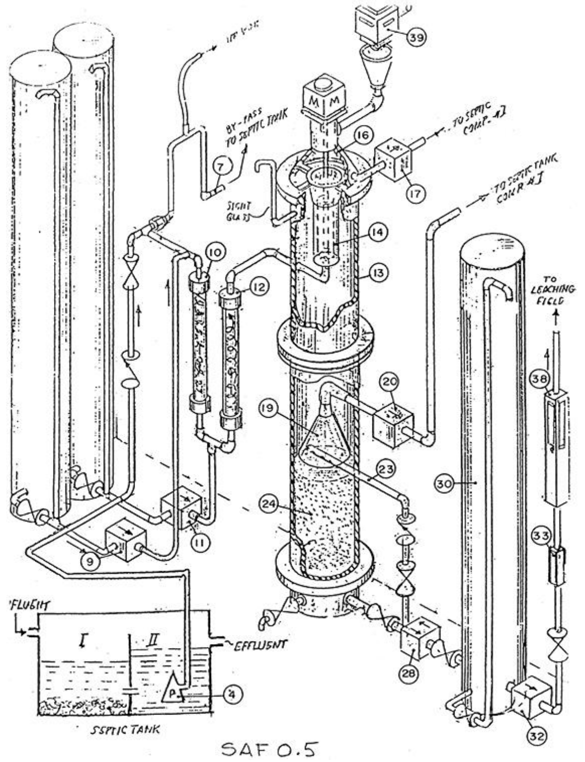


Figure 2B. Operational procedures and cycles of an electroflotation-filtration system (Note: Figure 2B is the continuation of Figure 2A)

FILTER CYCLE

Septic tank effluent is pumped (4) into the SAF 0.5 unit through a pipeline which connects the two. As this fluid enters the alum (10) flucculation cylinder, it is mixed with a concentrated solution of alum which is pumped to this point from it's storage tank by means of pump (9). The alum solution and the fluid swirl in this tank to form a precipitate called alum floc. The liquid and floc emerge from the cylinder where another chemical (polyelectrolyte) is added in a similar manner (11). The fluid then flows through a mixing cylinder (12) to a point in the tank (13) just below the electro-flotation unit (14). This unit electrically separates the molecules of hydrogen and oxygen in the water and, thereby, forms gaseous bubbles which immediately rise to the surface. These bubbles attach themselves to the floc (which has now entrapped a great deal of the foreign matter in the fluid) and cause it to rise. The matter, now buoyant, floats on the water surface and is collected (16) and returned to the front section of the septic tank by the sludge discharge pump (17). Gaseous materials are removed through vent and fan (39).

The fluid (which now fills tank) (13) is drawn down through the bottom of the tank by means of the discharge pump (32). As this water flows, it passes through a layer of sand (24) and a fine screen (25) where additional matter is filtered out. The water then passes through an ultra violet unit (38) (where bacteria and viruses are killed) back to the leach field.

Flow out of the filter is controlled by a flow meter (33). Flows into the system from pump (4) which are in excess of flows out of the system through pump (32) are bypassed back to the septic tank through the by-pass line (7).

BACKWASH CYCLE

As material builds on the surface of the sand, the flow through the sand decreases. In order to maintain flow in the system over any extended period of time, then, the sand must be cleansed periodically. This is accomplished by a timer (35) (not shown) which shuts off the influent flow and energizes the backwash cycle. During this short (20 sec) cycle, water is pumped by (28) back through the sand (24) from the clearwell (30). This lifts the foreign material from the surface of the sand. To facilitate this process, a small portion of the backwash water is diverted through (23) so as to cleanse the surface of the sand. The backwashed material is then collected in (19) and discharged back to the septic tank by means of pump (20).

6.2 Septic Tank Wastewater Treatment System

Lake water pollution is partially caused by the discharged of failing septic tank wastewater treatment system, legally known as the "failing onsite sewage disposal system"

Failing onsite sewage disposal system means an onsite sewage disposal system where the presence of raw or partially treated sewage on the ground's surface or in adjacent ditches or waterways or exposure to insects, animals, or humans is prima facie evidence of a system failure. Pollution of the groundwater or backup of sewage into plumbing fixtures may also indicate system failure. In order to prevent lake water pollution, it is necessary to under the common on-site septic tank wastewater treatment system.

The detailed technical information of an on-site septic system can be found from a recent literature [9]. When an on-site septic system is used by a property owner (either a home owner or an institutional owner), all water runs out of a house or institute from one main drainage pipe into a septic tank. A typical septic system consists of a septic tank and a drainfield (or soil absorption field). The septic tank digests organic matter and separates floatable matter (e.g., oils and grease) and solids from the wastewater. In conventional, or soil-based systems, the liquid (known as effluent) is discharged from the septic tank into a series of perforated pipes buried in a leach field, chambers, or other special units designed to slowly release the septic tank effluent into the soil. This area is known as the drainfield. The septic system disease-causing pathogens, nitrogen, phosphorus and other contaminants. Both the septic tank and the drainfield are described in detail in below.

The septic tank is a buried, water-tight container usually made of concrete, fiberglass, or polyethylene. Its functions are: (a) to hold the wastewater long enough to allow solids to settle down to the bottom forming sludge, while the oil and grease floats to the top as scum; and (b) partially and anaerobically treat the wastewater and sludge . Septic tank is a primary wastewater treatment unit. Compartments and a T-shaped outlet of the septic tank prevent the sludge and scum from leaving the tank and traveling into the drainfield area.

Septic tank effluent is the liquid wastewater (effluent) that exits the septic tank into the drainfield, or another wastewater treatment process. The sludge collected from the septic tank is called septage.

The drainfield is a shallow, covered, excavation made in unsaturated soil. The septic tank pretreated wastewater is discharged through piping onto porous surfaces that allow wastewater to filter through the soil for secondary wastewater treatment. The soil accepts, treats, and disperses wastewater as it percolates through the soil, ultimately discharging to groundwater. So the drainfield is a process facility for combined secondary treatment and ultimate disposal. If the drainfield is overloaded with too much liquid, it can flood, causing sewage to flow to the ground surface or create backups in toilets and sinks. The wastewater percolates into the soil, naturally removing harmful coliform bacteria, viruses and nutrients. Coliform bacteria predominantly inhabits the intestines of humans or other warm-blooded animals. It is an indicator of human fecal contamination.

6.3 Pollution Prevention for Lake Restoration

When a "failing onsite sewage disposal system" is identified, there are at least four options: (a) it can be repaired; (b) it can be replaced with a new septic tank wastewater treatment system; (c) construction of a new wastewater collection system for discharging the wastewater to a nearby Publicly Owned Treatment System (POTW) system; (d) installation of an "alternative discharging sewage treatment system or discharging system"; (e) installation of an "alternative onsite wastewater treatment system".

In case the existing failing septic system is beyond repair, construction of a new on-site septic system is impossible (for instance, new construction code is more stringent, therefore, a new septic system on-site is not allowed), and construction of a new POTW wastewater collection system is impossible (for instance, the property owner's site is far away from a POTW), the property owner can only consider either an alternative onsite wastewater treatment system, or an alternative onsite wastewater treatment system.

An alternative discharging sewage treatment system or discharging system is any device or system that results in a point source discharge of treated wastewater for which the government agency may issue a permit authorizing construction and operation when such system is regulated by the government permit issued for an individual single family dwelling with flows less than or equal to 1,000 gallons per day (gpd) on a monthly average.

An alternative onsite wastewater treatment system is a wastewater treatment works that is not a conventional onsite wastewater system and does not result in a point source discharge, and thus does not need a NPDES discharge permit in the USA.

The National Pollutant Discharge Elimination System (NPDES) is the US national program for (a) issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits and (b) imposing and enforcing pretreatment requirements under the Clean Water Act of the US Environmental Protection Agency (USEPA).

The LIWT has demonstrated that a combined dissolved air flotation (DAF) and filtration system (DAFF) is a feasible "alternative onsite wastewater treatment system" for pollution prevention and lake restoration by institutions [9].

This publication reports the results of another feasibility study involving the use smaller electroflotation-filtration (EFF) as an alternative onsite wastewater treatment system for pollution prevention and lake restoration by small property owners, such as single family or farm.

Table 2 summarizes the results of an EFF feasibility study for treatment of a septic tank effluent using the EFF system shown in Figure 1, Figure 2A and Figure 2B. Figure 1 shows a compact, home-size EFF (Krofta SAF 0.5; Lakeguard), designed to clarify septic tank effluent by eliminating phosphorous, suspended solids (to prevent plugging of the leaching field) and reducing odor to the point that the effluent can be reused in the toilets or used for watering the lawns. The goal of pollution prevention to a nearby lake can then be achieved.

Table 2. Treatment of septic tank effluent by electroflotation-filtration (Krota SAF-0.5)

Time Min.	Filter Back-Wash	Floc Eff. NTU	Flota Eff. NTU	Filter Effluent Quality Turb NTU	Color unit	pH unit	TSS ppm	COD ppm	NH_3-N ppm	NO_3-N ppm	PO_4-P ppm	Sludge Flow gpm	Sludge TSS ppm
0	NA	NA	NA	49	15	7	115	220	18.8	3.6	6.5	NA	NA
15				0.53									
30	BW			0.50	2	5	12				0.17	NA	S
45				0.48									
60	BW	29	50	0.46	0	5	11	24	18.7	0.4	0	.009	S
75				0.37									
90	BW			0.31	0	5	0				0.01	.009	S
105				0.43									
120	BW	32	32	0.49	0	5	6	20	12.3	0.3	0.03	.009	S
135				0.47									
150	BW			0.43	0	5	9				0.03	.009	S
165				0.40									
180	BW	28	30	0.36	0	5	8	18	12.7	0.4	0.02	.009	S
195				0.63		5							
210	BW			0.44	0	5	9				0.01	.009	S
225				0.48		5							
240	BW	40	35	0.37	0	5	7	20	12.5	0.3	0.01	.009	S

This unit uses electroflotation-filtration (EFF) instead of conventional independent physical-chemical system (chemical coagulation-flocculation, sedimentation and filtration) because of its simplicity for small plants and automatic operation. The following were the experimental conditions of the EFF feasibility study:

1. Influent = Septic tank effluent
2. Continuous influent flow rate = 0.36 gallon per minute (gpm);
3. Effluent flow rate = 0.35 gpm; (Note: 1 gallon = 3.785 liters)
4. Electroflotation sludge flow rate = 0.01 - 0.01 gpm;
5. Alum dosage = 10 parts per minute (ppm) as Al_2O_3;
6. Filter backwash time = 37 sec/backwash;
7. Cycle time (including waste discharge) = 2.2 min/cycle;
8. Volume of filter backwash water = 2.5-2.75 gallon/backwash
9. Conductivity = 150 micromhos/cm;
10. Alkalinity = 112 ppm as $CaCO_3$;
11. Septic tank effluent = EFF influent = Time at 0 min in Table 2.
12. Total sludge volume in 4 hours = 8176 mL = 2.16 gallons
13. Filtered effluent sampling point = EFF filter exit point.
14. Terminology: BW = backwash; NA = not available.
15. Performing organization = Lenox Institute of Water Technology

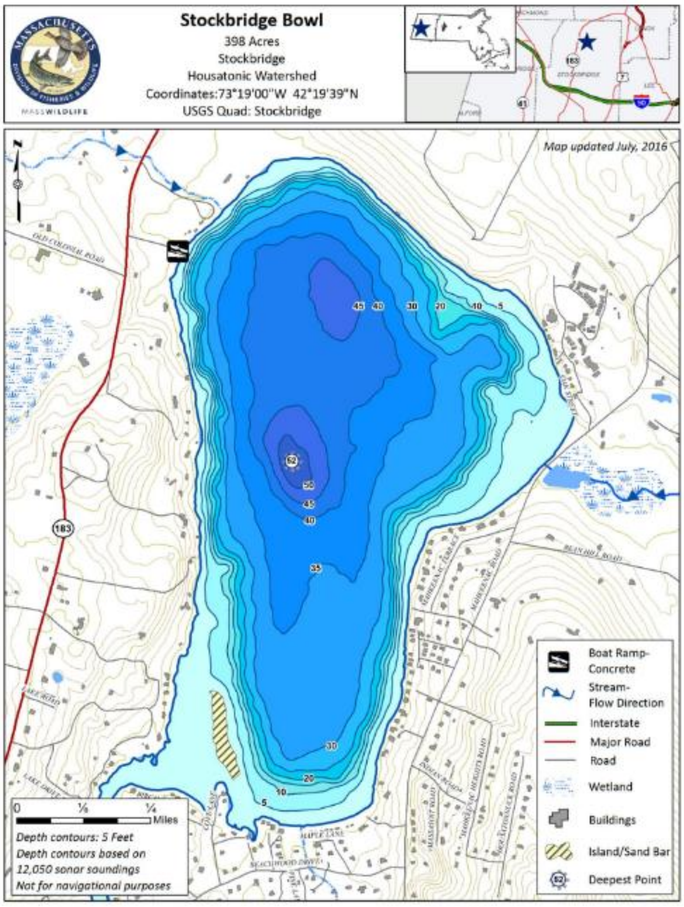
7: FEASIBILITY STUDY OF TREATING STOCKBRIDGE BOWL WATER BY ELECTROFLOTATION-FILTRATION FOR LAKE RESTORATION

7.1 Beautiful Stockbridge Bowl

Stockbridge Bowl, shown in Figure 3, is also known as Lake Mahkeenac, which, is a 398-acre artificially impounded "great pond" located off Route 183, Stockbridge, Massachusetts, USA. This beautiful lake is owned by the Commonwealth of Massachusetts, and is among the most heavily used water bodies in the Commonwealth. The lake has a maximum depth of 52 feet, an average depth of approximately 25 feet, and a shore length of 6 mi (9.7 km) . Its surface elevation is 930 ft and its out flow location is Larrywaug Brook. Above the lake's north side with sweeping views to the south is Tanglewood, the famous summer home of the Boston Symphony Orchestra, and the old home of the authors' Lenox Institute of Water Technology.

There is a causeway near the northeast shore of Stockbridge Bowl. On the other side of the causeway is Lily Brook Pond, which is the holding pond for Stockbridge Bowl. Long time ago, one could paddle a canoe under the causeway and into the lake, but, unfortunately, it is now impassible due to the buildup of algae, silt, beaver dams, and weeds. North of the Stockbridge Bowl causeway is the condominium community of White Pines. To the west of White Pines, on the north shore of the lake, is Camp Mah-Kee-Nac (a boy’s camp) operating from the end of June to mid-August.

Figure 3. Stockbridge Bowl, Berkshire County, Massachusetts, USA



7.2 Stockbridge Bowl Water Pollution

Over the past 77 years, the Stockbridge Bowl has been seriously polluted : (a) the lake has become choked with the invasive weed Eurasian water milfoil; (b) sedimentation has become the lake's second major problem and impacted docks; (c) zebra mussels have invaded the lake; and (c) the lake water quality has become poor with high concentration of algae and phosphorus. [12]

7.3. Planned Stockbridge Bowl Remediation

Possible remediation for lake restoration currently under consideration by the Commonwealth, the local government and the Stockbridge Bowl Association (SBA) are: (a) using a mechanical harvester to cut weed stems, several feet below the surface, to a level where they wouldn't interfere with recreational use of the lake; (b) a drawdown dredging, and hydro-raking; (c) instead of a drawdown, using fluridone, a narrow-spectrum herbicide that specifically targets milfoil. [12] All the above methodologies can solve the lake pollution problems temporarily. If the sources of lake pollution keeps on coming in, the water pollution problems can never be solved.

7.4. Recommended Stockbridge Bowl Water Pollution Prevention and Restoration

According to the authors, the long term solutions should be: (a) lake water pollution prevention (Section 6 of this chapter): preventing any point sources and non-point sources of pollution from entering the Stockbridge Bowl; (b) lake water quality restoration (Section 7 of this chapter): removing phosphorus (the limiting nutrient), the seeds of Eurasian water milfoil, zebra mussels, coliforms and algae from lake water, and (c) breeding weed-eating aquatic animals (fish, birds) in the lake. Dredging is still required if sedimentation of settleable matter in the lake is a serious problem.

The authors have recommended alternative solutions for lake water pollution prevention (Section 6 of this chapter and Reference [9]), and are recommending the use of electroflotation-filtration (EFF) as an alternative solution for lake water quality restoration.

7.5. Lake Restoration Using Electroflotation-Filtration

The same electroflotation-filtration (EFF) process unit illustrated in Figures 1, 2A and 2B were used in this lake water quality restoration research. The tested EFF is a physical-chemical process device which removes pollutants from the Stockbridge Bowl water, stores small amount of floated sludge and the backwash wastewater in a storage unit, and discharges the EFF effluent (meeting the NPDES permit standards) to the Stockbridge Bowl. The small EFF process unit is rectangular in shape with a dimensions of 3 ft W x 2 ft D x 6 ft H (0.9 m W x 0.6 m D x 1.8 m H) .

The following were the experimental conditions of the EFF lake restoration feasibility study:

1. Influent = Stockbridge Bowl water

2. Continuous influent flow rate = 0.36 gallon per minute (gpm);

3. Effluent flow rate = 0.35 gpm; (Note: 1 gallon = 3.785 liters);

4. Electroflotation sludge flow rate = 0.01 gpm;

5. Alum dosage = 10 parts per minute (ppm) as Al2O3;

6. Filter backwash time = 37 sec/backwash;

7. Cycle time (including waste discharge) = 2.2 min/cycle;

8. Volume of filter backwash water = 2.5-2.75 gallon/backwash

9. Conductivity = 131 micromhos/cm;

10. Alkalinity = 112 ppm as $CaCO_3$;

11. Stockbridge Bowl water = EFF influent = See Table 3.

12. Total sludge volume in 4 hours = 8176 mL = 2.16 gallons

13. Filtered effluent sampling point = EFF filter exit point.

14. Terminology: BW = backwash; NA = not available.

15. Performing organization = Lenox Institute of Water Technology.

Table 3 indicates the water quality of Stockbridge Bowl water sampled and tested by the LIWT. Experimental results are presented in Table 4.

Table 3. Water quality of Stockbridge Bowl water

PARAMETERS	DATA
pH, unit	8.5
Color, CU	20.0
Turbidity, NTU	2.5
Alkalinity, mg/L $CaCO_3$	112.0
Phosphate-P, mg/L	0.19
Aluminum, mg/L	0.12
Specific Conductivity, micromhos/cm	131
TSS, mg/L	104
COD, mg/L	35
Particle Count, #/100 mL	4000

NOTE: Sampled and analyzed by the Lenox Institute of Water Quality

Table 4. Treatment of Stockbridge Bowl water by electroflotation-filtration

Time Min.	Filter Back-Wash	Filter Effluent Quality: Turb NTU	Color unit	pH unit	TSS ppm	COD ppm	PO_4-P ppm	Al ppm	Particle Count #/100 ml
0	NA	2.5	20	8.5	104	35	0.19	0.12	4000
15		0.30							
30	BW	0.30	2	6.7			0		
45		0.28							
60	BW	0.30	2	6.7	0	10	0	0.05	10
75		0.25							
90	BW	0.26	1	6.7			0		
105		0.28							
120	BW	0.29	2	6.7	0	10	0	0.05	0
135		0.26							
150	BW	0.26	2	6.7			0		
165		0.26							
180	BW	0.27	2	6.7	0	18	0	0.05	20
195		0.28							
210	BW	0.26	1	6.7			0		
225		0.25							
240	BW	0.25	1	6.7	0	10	0	0.05	10

From the performance data summarized in Table 4, it appears that the texted electroflotation-filtration unit (Krofta Model SAF-0.5) has adequately treated the Stockbridge Bowl water in terms of the effluent turbidity (from 2.5 NTU to 0.25 NTU; 90% reduction); effluent color (from 20 to 1 color unit; 95% reduction); effluent TSS (from 104 mg/L to 0; 100 % reduction); effluent COD (from 35 mg/L to 10 mg/L; 71 % reduction); effluent phosphate-P (from 0.19 mg/L to zero; 100 % reduction); effluent aluminum (from 0.12 mg/L to 0.05 mg/L; 58 % reduction); and effluent particle counts (from 4000 #/100 mL to 10 #/mL; 99.7 % reduction).

7.6. Lake Water Treatment Using Flotation Technologies

The LIWT and KEC have jointly developed two technologies : (a) electroflotation-filtration (EFF) introduced here, and (b) dissolved air flotation (DAF) and filtration introduced elsewhere [9]. Both EFF and DAF-filtration are the only technologies presently available with high efficiency and small foot-print. They can treat enormous volumes of water in relatively small clarifiers and can effectively thicken the generated sludge to high consistency which can then be contained in relatively small sized containment vessels and easily disposed of. Their short treatment detention times, small sized clarifiers, high treatment efficiency, and high sludge consistency make them possible for the treatment of millions of gallons of lake water per day.

In this research, the authors used own LIWT facilities for the demonstration research. However, any manufacturers' flotation and/or filtration process equipment are expected to produce similar performance data, regardless of the shape (rectangular or circular) as long as the process equipment is chemically and physically optimized. A continuous pilot plant demonstration is required and the water quality samples (influent, effluent, sludge, etc.) must be analyzed by the State certified laboratories.

The keys for successful lake water treatment are: (a) the process equipment's foot-print, which must be small, light-weight, and shallow and (b) the process equipment costs and O&M costs must be affordable. The research engineers around the world are invited to study further, so an ultimate solution to lake pollution prevention and restoration can be found.

GLOSSARY OF LAKE POLLUTION, PREVENTION, AND RESTORATION [1-12]

Alkalinity or acid neutralizing capacity (ANC): (a) ANC describes the ability of the water to buffer any acidic inputs. This is typically low in some lakes in the New England States, USA, due to the lack of calcium in the soils and bedrock which underlies the lakes; (b) ANC is the acid neutralizing capacity of a solution, usually related to the amount of carbonates present; buffering capacity.

Alternative discharging sewage treatment system or discharging system: It means any device or system that results in a point source discharge of treated wastewater for which the government agency may issue a permit authorizing construction and operation when such system is regulated by the government permit issued for an individual single family dwelling with flows less than or equal to 1,000 gallons per day (gpd) on a monthly average.

Alternative onsite wastewater treatment system: It is a wastewater treatment works that is not a conventional onsite wastewater system and does not result in a point source discharge.

Anaerobic: (a) The absence of oxygen (refer to anoxic which is different although similar); (b) Living in the absence of oxygen. Some bacteria can survive and grow without oxygen present.

Anoxic: It is an environmental condition that the dissolved oxygen (DO) concentration in water is less than 0.5 mg/L.

Anoxic waters: They are areas of sea water, fresh water, or groundwater that are depleted of dissolved oxygen (DO) to below 0.5 mg/L.

Aquatic plants: It is a biological term used to describe a broad group of plants typically found growing in water bodies. The term may generally refer to both algae and macrophytes, but is commonly used synonymously with the term macrophyte.

Aquifer: It is a water-bearing layer of underground rock (including gravel and sand) that will yield water in usable quantity to a well or spring.

Chlorophyll-*a*: A green pigment in plants which is used to capture light energy and convert it, along with water and carbon dioxide, into food or organic material.

Chlorophyte algae: Bright green algae that occur in lakes as plankton, as well as forming tangled masses of filaments coming up from the lake bottom or near shorelines. This group does especially well in warm water and bright light and is usually abundant in summer. The species are very diverse, including several that look more like grassy aquatic plants than algae. Another species, Botryococcus, turns bright orange under certain conditions, but is not toxic like the marine red tides.

Chrysophyte algae: Golden algae that are common members of the plankton in small lakes. They can be solitary or make colonies with large numbers of individuals. Some species make a protective silica sheath around the cells or have a covering of siliceous scales that preserve in lake sediments and have been used for reconstruction studies of past lake environments.

Conventional onsite sewage system: It means a treatment works consisting of one or more septic tanks with gravity, pumped, or siphoned conveyance to a gravity distributed subsurface drainfield.

Cultural eutrophication: The acceleration of the natural eutrophication process caused by human activities, occurring over decades as opposed to thousands of years.

Cyanobacteria (blue-green algae): Bacteria that photosynthesize (use sunlight to produce food) and are blue-green in color. While cyanobacteria occur naturally in all lakes and ponds, elevated nutrient levels may cause cyanobacteria to "bloom" or grow out of control and cover the lake surface. The concern associated with cyanobacteria is that some species produce toxins that may affect domestic animals or humans through skin contact or ingestion. These toxins may cause a variety of symptoms, including nausea, vomiting, diarrhea, fever, skin rashes, eye and nose irritations, and general malaise. If you see a cyanobacteria bloom do not go in the water, do not drink the water, and do not let pets or livestock go in or drink the water.

Dissolved air flotation (DAF): One of dissolved gas flotation (DGF) processes when air is used for generation of gas bubbles. A typical example is Krofta Engineering Corporation's Supracell clarifier; See dissolved gas flotation (DGF).

Dissolved air flotation-filtration (DAFF): A package plant which consists of both dissolved air flotation and filtration. A typical example is Krofta Engineering Corporation's Sandfloat clarifier.

Dissolved gas flotation (DGF): It is a process involving pressurization of gas at 25 to 95 psig for dissolving gas into water, and subsequent release of pressure (to one atm) under laminar flow hydraulic conditions for generating extremely fine gas bubbles (20-80 microns) which become attached to the impurities to be removed and rise to the water surface together. The impurities or pollutants to be removed are on the water surface are called float or scum which scooped off by sludge collection means. The clarified water is discharged from the flotation clarifier's bottom. The gas flow rate is about one percent of influent liquid flow rate. The attachment of gas bubbles to the impurities can be a result of physical entrapment, electrochemical attraction, surface adsorption, and/or gas stripping. The specific gravity of the bubble-impurity agglomerate is less than one, resulting in buoyancy or non-selective flotation (i.e. Save-All).

Drainfield: The drainfield is a shallow, covered, excavation made in unsaturated soil. The septic tank pretreated wastewater is discharged through piping onto porous surfaces that allow wastewater to filter through the soil for secondary wastewater treatment. The soil accepts, treats, and disperses wastewater as it percolates through the soil, ultimately discharging to groundwater. So the drainfield is a process facility for combined secondary treatment and ultimate disposal. If the drainfield is overloaded with too much liquid, it can flood, causing sewage to flow to the ground surface or create backups in toilets and sinks. The wastewater percolates into the soil, naturally removing harmful coliform bacteria, viruses and nutrients. Coliform bacteria predominantly inhabits the intestines of humans or other warm-blooded animals. It is an indicator of human fecal contamination.

Electroflotation: It is process involving the generation of hydrogen and oxygen bubbles in a dilute electrolytic aqueous solution by passing a direct current between two electrodes (a) anode and (b) cathode. Anode reaction generates oxygen bubbles and hydrogen ions; while cathode reaction generates hydrogen bubbles and hydroxide ions. Either aluminum or steel sacrificial electrodes can be employed for generating the gas bubbles as well as coagulants at the same time. Non-sacrificial electrodes are employed for generating the gas bubbles only, and can be mode of titanium (as the carrier material) and lead dioxide (as the coating material). Electrical power is supplied to the electrodes at a low voltage potential of 5 to 20 volts DC by means of a transformer rectifier. Small bubbles in the range of 20-50m microns are produced under laminar hydraulic flow conditions feasible for flotation separation of fragile flocs from water in a small system. The floats on the water surface are the impurities/pollutants removed from water. The clarified water is discharged from the flotation clarifier's bottom. There can be unexpected advantages and disadvantages when electroflotation is employed. For instance, chlorine bubbles may be generated as a water disinfectant if the water contains significant amount of chloride ions. Certain unexpected gas bubbles may be generated and may be undesirable.

Electrolytic flotation: Same as Electroflotation.

Epilimnion: (a) The upper, well-circulated, warm layer of a thermally stratified lake; (b) The warmer, less dense, upper layer of a lake lying above cooler water (metalimnion and hypolimnion) in some seasons of the year.

Eutrophic: (a) A trophic state (degree of eutrophication) in which a lake or pond is nutrient rich and sustains high levels of biological productivity. Dense macrophyte growth, fast sediment accumulation, frequent algae blooms, poor water transparency and periodic oxygen depletion in the hypolimnion are common characteristics of eutrophic lakes and ponds; (b) Nutrient rich waters, generally characterized by high levels of biological production. (Refer to mesotrophic and oligotrophic) ; (c) Waters in which algae grow into large populations and biovolumes, generally related to nutrient supply. Trophic state indicators above 50 are classified as eutrophic.

Eutrophication: It is an environmental process that (a) involves the gradual increase in the concentration of phosphorus, nitrogen, and other plant nutrients in an aging aquatic ecosystem; (b) results an excessive richness of nutrients in a lake, or pond, or river bend frequently due to decay of natural humic substances, storm runoff from the land, point-source pollution (such as septic tank effluent), non-point source pollution (such as agricultural wastewater discharges) , etc. and (c) causes a dense growth of plant life and death of aquatic animal life from lack of oxygen.

Failing alternative discharging sewage treatment system: It means any alternative discharging sewage treatment system that discharges effluent having a $BOD_{5,}$ total suspended solids, pH, chlorine residual, dissolved oxygen, or bacteria value that is out of compliance with the The failure to discharge due to exfiltration may indicate system failure.

Failing onsite sewage disposal system: It means an onsite sewage disposal system where the presence of raw or partially treated sewage on the ground's surface or in adjacent ditches or waterways or exposure to insects, animals, or humans is prima facie evidence of a system failure. Pollution of the groundwater or backup of sewage into plumbing fixtures may also indicate system failure.

Fall Turnover: The mixing of thermally stratified waters that commonly occurs during early autumn. The sequence of events leading to a turnover includes: cooling of surface waters leading to a density change in surface water that produces convection currents from top to bottom, and circulation of the total water volume by wind action. Turnover generally results in uniformity of the physical and chemical properties of the water.

Humic Substances: Organic substances incompletely broken down by decomposers such as bacteria. Humic acids are large molecular organic acids that are present in water, often giving the water a yellow or brown color.

Hypolimnion: The colder, dense, deep water layer in a thermally stratified lake, lying below the metalimnion and removed from surface influences.

Lake eutrophication: It is an environmental condition that excessive richness of nutrients (phosphorus and nitrogen) in a lake or other body of water, frequently due to storm runoff from the land, point-source pollution (such as septic tank effluent), non-point source pollution (such as agricultural wastewater discharges) , etc. which causes a dense growth of plant life and death of animal life from lack of oxygen.

Limiting Nutrient: Essential nutrient for algae that is available in the smallest amount in the environment, relative to the needs of the organisms.

Limnology: It is the study of the biological, chemical, and physical features of inland mainly fresh waters including lakes, ponds, rivers, springs, streams , wetlands and other bodies of semi-fresh water.

Mesotrophic: (a) Waters containing an intermediate level of nutrients and biological production. (Refer to eutrophic and oligotrophic); (b) Waters that promote algae growth at rates intermediate between eutrophy and oligotrophy. Trophic state indicators between 40 and 50 are classified as mesotrophic.

Metadata: Documentation about a sample or collection that describes pertinent background information, including field information (original geographic location, collector, date, specimen number), the nature of the material, and any associated descriptive characteristics.

Metalimnion: The layer of water in a lake between the epilimnion and hypolimnion in which the temperature, and thus density, change rapidly over a short distance.

Monomictic (cold lakes): Lakes with water temperatures never greater than 4 ^{o}C and with only one period of circulation in the summer. These lakes are typically found in the Arctic or mountains and although they may be ice-free for brief periods in the summer, they are in frequent contact with glaciers or permafrost.

Monomictic (warm lakes): (a) Lakes with water temperatures that do not drop below 4 ^{o}C and circulate freely in the winter. These lakes stratify directly in the summer. Warm monomictic lakes are common to warm regions of the temperate zones, in particular in areas influenced by ocean climates and in mountainous areas of subtropical latitudes; (b) A water pattern of lakes in which thermal mixing and stable stratification alternate once per year.

Morphometry: A term that refers to the depth contours and dimensions (topographic features) of a lake or pond.

National Pollutant Discharge Elimination System (NPDES): It is the US national program for (a) issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits and (b) imposing and enforcing pretreatment requirements under the Clean Water Act of the USEPA.

Nonpoint Source: A source of pollutants to the environment that does not come from a confined, definable source such as a pipe. Common examples of non-point source pollution include urban runoff, septic system leachate, and runoff from agricultural fields.

Nonpoint Source Pollution: Pollution from diverse sources difficult to pinpoint as separate entities and thus more complicated to control or manage. Examples of “nonpoint sources” include area-wide erosion (as opposed to landslides or mass wasting), widespread failure of septic systems, certain farming practices or forestry practices, and residential/urban land uses (such as fertilizing or landscaping).

Nutrient: (a) Any chemical element, ion, or compound required by an organism for growth and reproduction; (b) Elements or chemicals required to sustain life, including carbon, oxygen, nitrogen and phosphorus.

Nutrient Limitation: The limitation of growth imposed by the depletion of an essential nutrient.

Oligotrophic: Waters that are nutrient poor and which, as a result, have little algal production. Trophic state indicators below 40 are classified as oligotrophic.

Phosphorus: One of the elements essential for growth and reproduction. Phosphorus is often the limiting or least available nutrient for plant growth in temperate freshwater ecosystems. The primary original source of phosphorus is from the earth in the form of phosphate rocks.

Photic zone: The upper water in a lake in which light penetrates enough to enable plants to carry out photosynthesis.

Photosynthesis: (a) The process by which plants use chlorophyll to convert carbon dioxide, water and sunlight to oxygen and cellular products (carbohydrates); (b) The production of organic matter (carbohydrates) from inorganic carbon and water, utilizing the energy of light.

Phytoplankton: (a) Algae that float or are freely suspended in the water.; (b) Free floating microscopic organisms that photosynthesize (algae and cyanobacteria).

Point source discharge: It is any discernible, confined, and discrete conveyance including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel, or other floating craft from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture or agricultural stormwater run-off.

Point Source Pollution: Pollution into a water body from a specific and identifiable source, such as industrial waste or municipal sewers.

Pollutants: Elements and compounds occurring naturally or man-made introduced into the environment at levels in excess of the concentration of chemicals naturally occurring.

Sedimentation: The transport and deposition of sediment particles by flowing water.

Seepage meter: A device used to measure the groundwater volume entering a lake, pond or stream over time.

Septage: The sludge collected from the septic tank is called septage.

Septic system: All water runs out of a house or institute from one main drainage pipe into a septic tank. A typical septic system consists of a septic tank and a drainfield (or soil absorption field). The septic tank digests organic matter and separates floatable matter (e.g., oils and grease) and solids from the wastewater. In conventional, or soil-based systems, the liquid (known as effluent) is discharged from the septic tank into a series of perforated pipes buried in a leach field, chambers, or other special units designed to slowly release the septic tank effluent into the soil. This area is known as the drainfield. The septic system disease-causing pathogens, nitrogen, phosphorus and other contaminants.

Septic tank effluent: It is the liquid wastewater (effluent) that exits the septic tank into the drainfield, or another wastewater treatment process.

Septic tank: The septic tank is a buried, water-tight container usually made of concrete, fiberglass, or polyethylene. Its functions are: (a) to hold the wastewater long enough to allow solids to settle down to the bottom forming sludge, while the oil and grease floats to the top as scum; and (b) partially and anaerobically treat the wastewater and sludge . Septic tank is a primary wastewater treatment unit. Compartments and a T-shaped outlet of the septic tank prevent the sludge and scum from leaving the tank and traveling into the drainfield area.

Surface waters: It includes: (a) All waters that are currently used, were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters that are subject to the ebb and flow of the tide; (b) All interstate waters, including interstate wetlands; (c) All other waters such as intrastate lakes, rivers, streams (including intermittent streams), mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds and the use, degradation, or destruction of which would affect or could affect interstate or foreign commerce including any such waters: (c1) That are or could be used by interstate or foreign travelers for recreational or other purposes; (c2). From which fish or shellfish are or could be taken and sold in interstate or foreign commerce; or (c3) That are used or could be used for industrial purposes by industries in interstate commerce; (d) All impoundments of waters otherwise defined as surface waters under this definition; (e) Tributaries of waters identified in subdivisions 1 through 4 of this definition; (f) The territorial sea; and (g) Wetlands adjacent to waters, other than water that are themselves wetlands, identified in subdivisions 1 through 6 of this definition..

Thermal stratification: (a) A process by which a deep lake becomes layered by temperature in the summer months. The layers will separate because colder water sinks to the bottom, leaving warmer water at the surface. Because these layers form chemical and biological barriers, limnologists sample at each layer of the lake. During the winter months, when ice forms on the lake, Inverse Thermal Stratification occurs under the ice, in which colder, less dense water overlies warmer, denser water near the maximum density of four degrees Celsius; (b) The process by which a lake or pond forms several distinct thermal layers. The layers include a warmer well-mixed upper layer **(epilimnion),** a cooler, poorly mixed layer at the bottom (**hypolimnion),** and a middle layer **(metalimnion**) that separates the two.

Thermocline: (a) A term that refers to the plane of greatest temperature change within the **metalimnion.** Often used interchangeably with metalimnion.; (b) The point of maximum temperature decrease with depth in a thermally stratified lake (in a vertical section of lake water). Transparency: A measure of water clarity often determined by the depth at which a Secchi disk can be seen below the surface of the water. Transparency may be reduced by the presence of algae and suspended materials such as silt and pollen.

Total Kjeldahl nitrogen (TKN):, essentially the sum of ammonia nitrogen and organic forms of nitrogen.

Trophic classification: Biologically ranking the quality of lakes using a model that incorporates several parameters. In the State of New Hampshire, USA, for instance, these parameters are: chlorophyll-a, Secchi disk transparency, aquatic plant abundance, and dissolved oxygen.

Trophic state: (a) The trophic state of a lake is a general concept with no precise definition and no well-defined units of measure. In general, trophic state refers to the biological production, both plant and animal life, that occurs in a lake. The level of production that occurs is defined by several factors, but primarily by the phosphorus supply to the lake and the volume and residence time of the water in the lake. (Refer to Oligotrophic, Mesotrophic, Eutrophic); (b) A term used to describe the productivity of a lake ecosystem classifying it as one of three increasing categories based on algal biomass: oligotrophic, mesotrophic, or eutrophic. Trophic state indicators are calculated on the basis of total phosphorus, chlorophyll-a and secchi transparency measurements.

Turbidity: A measure of the particles suspended in the water column which affect the clarity and transparency of the water. These particles may include silt, clay, and algae.

Turnover: The mixing of lake water from top to bottom after a period of stable stratification. This typically occurs in fall and is caused by wind and seasonal cooling of surface waters.

Water well or well: It is any artificial opening or artificially altered natural opening, however made, by which groundwater is sought or through which groundwater flows under natural pressure or is intended to be artificially drawn. This definition shall not include wells drilled for the following purposes: (a) exploration or production of oil or gas, (b) building foundation investigation and construction, (c) elevator shafts, (d) grounding of electrical apparatus, or (e) the modification or development of springs.

Water year (WY): A division of the earth year based on the general pattern of annual wet and dry periods rather than by calendar months. The U.S. Geological Survey uses the water year of October 1 through September 30 for data analysis.

Watershed: The land area draining to a particular water body. A watershed is often described as a funnel, where the lake or river is the bottom of the basin, collecting all the water that falls inside the funnel.

Watershed management: Implementing practices within a watershed designed to protect or restore the water quality of the receiving water body. Such practices may include the implementation of Best Management Practices.

Watershed districts and ordinances: Methods of zoning that recognize watershed boundaries instead of political boundaries as a means of regulating land uses that may affect surface water quality. A watershed district or ordinance may implement regulations in the watershed in order to protect surface waters such as streams and lakes. Some of the regulations include: land use restrictions, buffer strip requirements, low-impact development, and best management practices

Zooplankton: Small animals found in the water of lakes that possess limited powers of locomotion, and which feed on bacteria, algae, smaller animals, and organic detritus present in the water.

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APPENDIX

INTRODUCTION OF THE EDITORS OF ENVIRONMENTAL SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM) SERIES

1. Editor Lawrence K. Wang

Editor Lawrence K. Wang has served the society as a professor, inventor, chief engineer, chief editor and public servant (UN, USEPA, New York State) for 50+ years, with experience in entire field of environmental science, technology, engineering and mathematics (STEM). He is a licensed NY-MA-NJ-PA-OH Professional Engineer, a certified NY-MA-RI Laboratory Director, a licensed MA-NY Water Operator, and an OSHA Instructor. He has special passion, and expertise in developing various innovative technologies, educational programs, licensing courses, international projects, academic publications, and humanitarian organizations, all for his dream goal of promoting world peace. He is a retired Acting President/Professor of the Lenox Institute of Water

Technology, USA, a Senior Advisor of the United Nations Industrial Development Organization (UNIDO), Vienna, Austria, and a former professor/visiting professor of Rensselaer Polytechnic Institute, Stevens Institute of Technology, University of Illinois, National Cheng-Kung University, Zhejiang University, and Tongji University. Dr. Wang is the author of 750+ papers and 50+ books, and is credited with 29 invention patents. He holds a BSCE degree from National Cheng- Kung University, Taiwan, ROC, a MSCE degree from the University of Missouri, a MS degree from the University of Rhode Island and a PhD degree from Rutgers University, USA. Currently he is the book series editor of CRC Press, Springer Nature Switzerland, Lenox Institute Press, World Scientific Singapore, and John Wiley. Dr. Wang has been a Delegate of the People to People Internatonal Foundation, a Diplomate of the American Academy of Environmental Engineers, a member of ASCE, AIChE, ASPE, WEF, AWWA, CIE and OCEESA, and a recipient of many US and international engineering and science awards.

2. Editor Mu-Hao Sung Wang

Editor Mu-Hao Sung Wang has been an engineer of the New York State Department of Environmental Conservation, an editor of CRC Press, Springer Nature Switzerland, and Lenox Institute Press, and a university professor of the Stevens Institute of Technology, National Cheng-Kung University, and the Lenox Institute of Water Technology. Totally she has been a government official, and an educator in the USA and Taiwan for over 50 years. Dr. Wang is a licensed Professional Engineer, and a Diplomate of the American Academy of Environmental Engineers (AAEE). Her publications have been in the areas of water quality, modeling, environmental sustainability, solid and hazardous waste management, NPDES, flotation technology, industrial waste treatment, and analytical methods. Dr. Wang is the author of over 50 publications and an inventor of 14 US and foreign patents. She holds a BSCE degree from National Cheng-Kung University, Taiwan, ROC, a MS degree from the University of Rhode Island, RI, USA, and a PhD degree from Rutgers University, NJ, USA. She is the Co-Series Editor of the Handbook of Environmental Engineering series (Springer Nature Switzerland), Coeditor of the

Advances in Industrial and Hazardous Wastes Treatment series (CRC Press of Taylor & Francis Group) and the Coeditor of the Environmental Science, Technology, Engineering and Mathematics series (Lenox Institute Press). She is a member of AWWA, NYWWA, NEWWA, WEF, NEWEA, CIE and OCEESA.

3. Editor Yuriy I. Pankivskyi

Dr. Yuriy I. Pankivskyi has 25 years of professional experience of scientific research and environmental education. He has expertise in strategic environmental assessment, environmental impact assessment, drinking water treatment, waste waters treatment, water and air pollution control, solid waste management. He works as environmental consulting engineer for industrial enterprises, state administrations of cities and towns of Western Ukraine, communities, private firms and institutions and as researcher, educator for state universities. He is the Associate Professor and Deputy Head of Department of Ecology of Ukrainian National University of Forestry. His research and publications have been in areas of water and air quality control, waste water treatment, environmental sustainability and education, analytical methods, investigations of multifunctional material for optoelectronics and environment testing. Dr. Pankivskyi is author of over 70 scientific publications. He earned his Specialist degree from Lviv State Ivan Franko University (Ukraine), ME degree from Lenox Institute of Water Technology (MA, USA), and his PhD degree from Lviv National Ivan Franko University (Ukraine). He is a member of National Ecological Center of Ukraine (Lviv Department).