Efficient Plants and Procedures for Wastewater Treatment

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***Abstract*-As part of general environmental protection measures, simple, easy-to-maintain and efficient water treatment installations are necessary for the treatment of wastewater from isolated buildings, from transport vehicles (which cannot be connected to a public sewage network) and from industrial enterprises that evacuate great concentrations of oil and fat into the public sewage network. This study describes two plants designed for local wastewater treatment: (1) an autonomous plant, containing self-cleaning filters for wastewater treatment from buildings and transport vehicles (trains, mobile homes, and boats); (2) a small plant for housing wastewater treatment from isolated buildings (vacation houses, fuel distribution stations and their annexes) or wastewater from industrial enterprises with their own low-capacity purification stations. Additionally, we present an efficient cavitation air flotation system which isolates fats, oils and solid particles from the wastewater of cities and industrial areas in a colloidal suspension; this system adequately processes the wastewater from the particles to be evacuated. By promoting the proposed solutions, optimal hygiene and public health conditions can be assured by avoiding water, soil and air pollution in these community areas.**

Keywords- Environmental Protection; Wastewater Treatment; Efficient Local Plants; Cavitation Air Location

I. INTRODUCTION

Wastewater treatment plants are major investments due to the high capital required to build them as well as their high operating and maintenance costs [1]. Moreover, small and isolated villages or settlements with low population densities can be served by decentralized systems that are simple and low in cost [2-4].

The necessity of local sewage systems has increased due to the construction of numerous isolated buildings (vacation houses, and gas stations with their annexes) located outside cities [5]. Within general environmental protection activities, wastewater originating from isolated buildings and transportation vehicles (that cannot be connected to a public sewage network) should have access to treatment plants that are simple, economic and efficient in order to reduce pollution factors [6,7], thereby preventing the spread of infectious diseases, unpleasant smells and damaging gases.

Additionally, industrial enterprises evacuate great concentrations of oils and fat waste into the water of public sewage networks. The isolation of these substances is essential to conventional purification [8] and leads to the reduction of pollution. Flotation is a purification procedure for wastewater that involves separating the fine divided substances and fats and transforming them into floating substances [9]. The treatment of wastewater has become an industry for the production of valuable products as well as a necessity for maintaining requirements of environmental protection [10, 11].

This paper describes an autonomous plant which contains self-cleaning filters for wastewater treatment in buildings and transportation vehicles (trains, mobile houses, and boats) as well as a small plant for the treatment of domestic wastewater or of wastewater from industrial enterprises with their own reduced-capacity treatment plants. Additionally, we present an efficient cavitation air flotation system that isolates fats, oils and solid particles from the wastewater of cities and industrial areas in a colloidal suspension; this system adequately separates the wastewater from the particles to be evacuated.

II. AUTONOMOUS PLANT FOR WASTE WATER TREATMENT

Autonomous plants for wastewater treatment [12] are characterized by the presence of a toilet basin; a tank with a constant level; a chamber for waste treatment containing a filtering layer that is resistant to damage; and a porous, self-cleaning filter made of two conductor elements and generally metallic. Wastewater is separated through a filtering material, such as sand, in this filtering layer. This filter has the potential to establish an electric potential for the production of an electrolytic current between metallic elements.

The first of the porous metallic elements to pass through the wastewater acts as a membrane by producing a negative charge on the element and releasing bubbles of gaseous hydrogen that dislocate semisolid parts from the material that is being filtered. The hydrogen release produces a relatively high pH, leading to the coagulation of the colloidal substance and to sludge sedimentation, which is subsequently disposed of or, preferably, recycled in the treatment chamber to activate sediments and to increase the efficiency of the absorption of solid residue.

Oxygen and chlorine, which are required to oxidize solid residues and disinfect the water, are released into the second metallic element, which is positively charged. The solid residue and disinfected water can then be recycled in the tank at a

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constant level, or evacuated. The plant (Fig. 1) includes the following primary elements: a chamber for waste treatment and a self-cleaning filter.

Several rows of plastic plates with a perforated bottom are contained in the chamber for waste treatment. Each plate has a damage resistant layer of filtering material, to act as a filter with reduced discharge. Simultaneously, the filtering environment also absorbs the waste. As wastewater passes through the filter with reduced discharge, it is subjected to bacterial decomposition produced by the absorbed sediments, and is converted from solid waste into liquid effluent. Water subjected to cleaning in the treatment chamber passes through the self-cleaning filter, to be evacuated to the tank and recycled into the system after filtration. The solid material (sludge) collected with the filter is then disposed of above of the treatment chamber.

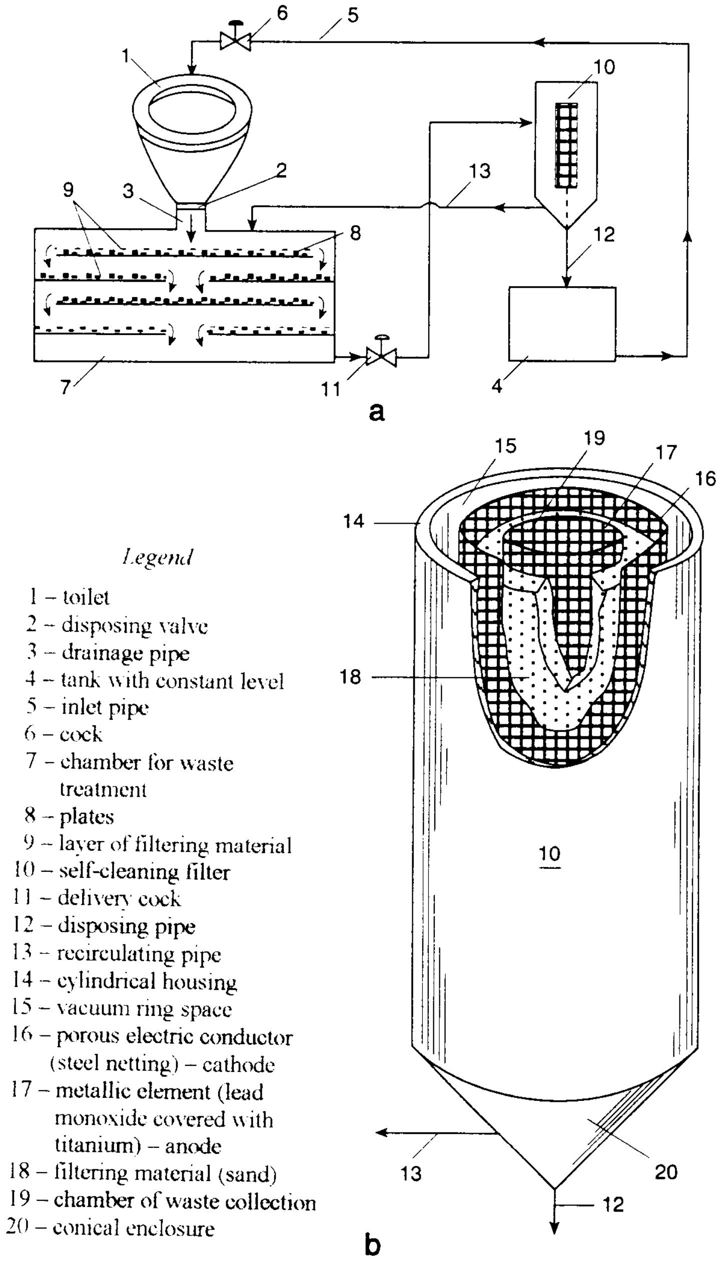

Fig. 1 Autonomous plant for waste water treatment

(a) scheme of the plant; (b) self-cleaning filter

The self-cleaning filter, shown in Fig. 1(b), is made of a cylindrical housing unit which surrounds a vacuum ring space, in which the water enters from the chamber for waste treatment and passes through a porous, cylindrical electric conductor made of steel netting. This conductor is located on a common axle with with a second metallic element of a smaller diameter, which consists of lead monoxide covered with titanium, a filtering material (i.e., sand) and an electric insulator (generally non-metallic and inorganic) between the metallic elements. A central collection room of cleaned water is located on the filter axle, which communicates with the discharge pipe at the bottom of the housing and has a conical enclosure that communicates with

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the inlet ring space to collect sludge, which is subsequently disposed of. The self-cleaning filter also includes a tank (not shown) to produce an electrolytic current due to the difference in electrical potential between the external element with a negative charge that acts as a cathode and the inside element with positive charge that acts as an anode.

The application of an electric potential of 5–30 V between the anode and the cathode produces the release of hydrogen in the external element and the release of oxygen and chlorine in the internal element. The released hydrogen tends to remove the solid material collected on the filtering element before the application of the electrical potential. This produces the coagulation of colloidal particles, leading to the sedimentation of sludge in the conical enclosure. This action of sedimentation is intensified by the increase in pH facilitated by the release of hydrogen in the inlet ring space.

The combined effect of oxygen and chlorine released in the internal element is the oxidization of the solid materials remaining in the filtered liquid effluent and the chlorination of the cleaned water, which, together with the electrolytic current, eliminate the activity of bacteria. Additionally, the release of these gases tends to lower the pH of the filtered effluent so that the cleaned water may be reused in the system for waste treatment.

The use of the presented plant provides the following advantages:

– The introduction of a self-cleaning filter increases the efficiency of effluent filtering. It may be used for a long time, and it eliminates bacteria from the effluent without the addition of chlorine or other chemical bactericides;

– A reduction of investment and operation costs;

– The simplification of plant operation;

– The self-cleaning filter may be used beyond the field of wastewater treatment, i.e., everywhere the filtration of an electrolytic liquid or sedimentation is required, because the disposal of a solution with solid particles allows them to be separated without difficulty.

III. SMALL SEWAGE TREATMENT PLANT

The installation of wastewater treatment plants with reduced dimensions [13] that are made from a plastic material allows the placement of such plants in locations with reduced equipment capacities for properly operating the machine and its components. The scheme of this plant is presented in Fig. 2, which includes a parallelepiped tank with an access hole on top, a supply pipe on the sides, and a discharge pipe. The inside of the tank is subdivided into three areas that communicate with each other: the inlet area, the aeration area and the decantation area.

An inlet chamber formed by a tube that is open at the bottom and top is located in the inlet area. The lower end of the tube is passed through a pipe that distributes compressed air. Inside the tube, an agitator is operated by an electric motor.

In the aeration area, equally-spaced plate packages made of a synthetic material are located at an incline of approximately 3º, under which the ejection orifices are placed. The plates are even on one side and on the other side have profiles with channels opened to the bottom and horizontally directed.

The decantation area is separated from the aeration area by a wall that extends the entire length of the tank, with the lower part inclined at an angle of approximately 45º, creating a section separated from the tank bottom; this forms a connection between the two areas.

The tank is permanently filled with wastewater to the level of the discharge pipe. Using a compressor (not shown), air is constantly discharged, and passes through the ejection orifices and the aeration area from the bottom to the top. The remaining air bubbles are retained on plates in the channels and are soon pushed away by subsequent bubbles.

Wastewater contained in the aeration chamber enters into intensive contact with the air, and in the case of flowing wastewater the water cleaned in the aeration area is discharged in the decantation area, where it slowly rises. The air that passes through part of the distribution pipe, directly located under the oblique bottom of the separation wall, produces aspiration so that the activated sludge on the wall is brought into the aeration area.

When wastewater appears in the supply pipe, it immediately enters the inlet chamber without perturbing the aerobic cleaning process that takes place in the aeration area. Coarse residue (e.g., feces) from this water is broken up in the inlet chamber; the breaking action is assured by the turbulence provided by the ascendant current of air bubbles that passed through the distribution pipe. The agitator, using a mixing arm, contributes to the rapid and intensive breaking action. By using a switch, the agitator is operated either for a short period or at intervals each time a flow of wastewater enters the inlet chamber.

The execution and use of the plant previously described provides the following advantages:

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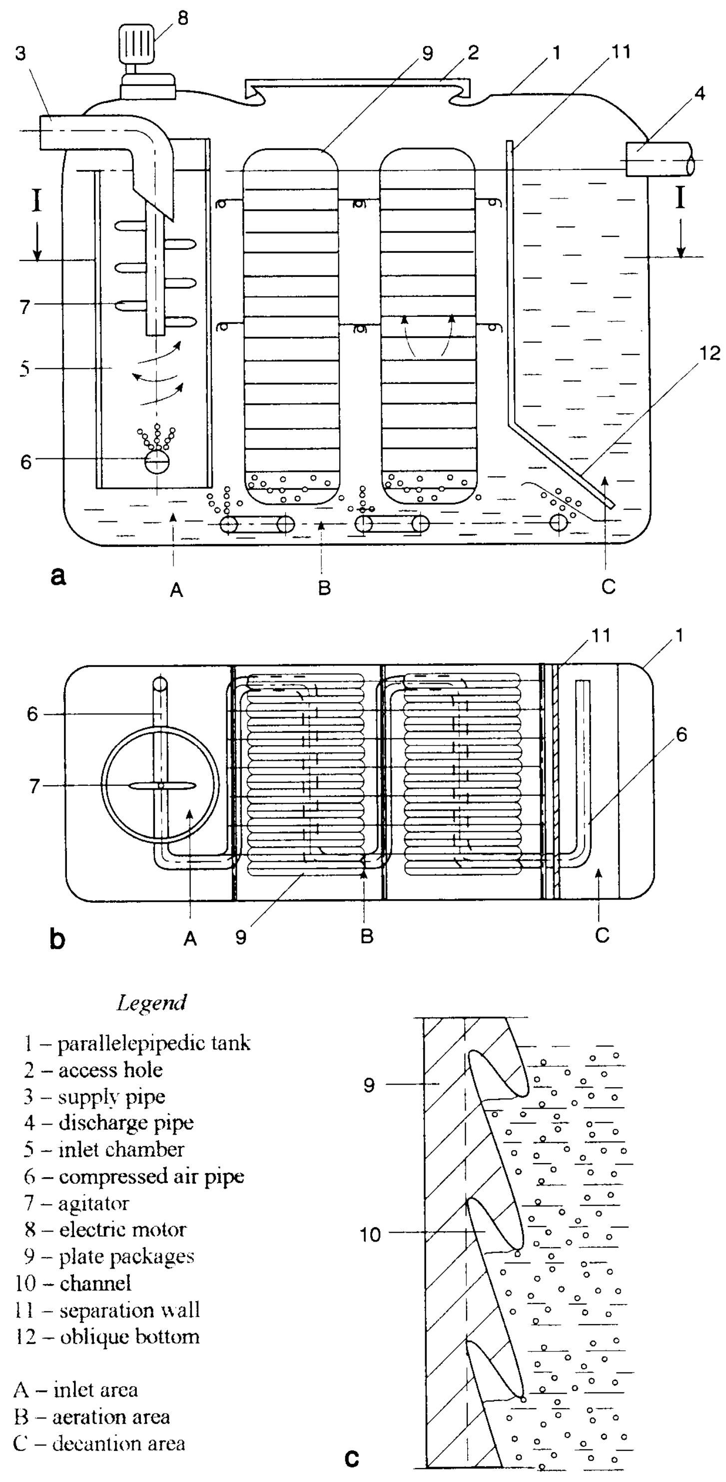

Fig. 2 Plant for wastewater treatment scheme

(a) scheme; (b) horizontal section I-I; (c) detail

– The breakage of rough impurities in the wastewater in the inlet chamber leads to a substantial rise in the action surface of aerobic bacteria in the aeration area, leading to rapid cleaning;

– The plates provided in the aeration chamber represent obstacles that considerably increase the contact time between the water subjected to cleaning and air bubbles; because of this, the energy required to compress the air is reduced, resulting in appreciable energy savings;

– The advantageous engineering and placement of all devices in a single tank that can be easily mounted provides better cleaning of the wastewater than a complex unit with a capacity lower than that required by traditional plants;

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– A reduction of metal consumption and reinforced concrete (cement and steel concrete).

The main disadvantage of this plant is its reduced capacity to serve only small villages.

IV. THE CAVITATION AIR FLOTATION SYSTEM

The most common flotation system used for the purification of wastewater is the dissolved air flotation (DAF) system, which requires pressurized tanks, air compressors, recirculation pumps, high-pressure pumps and great energy consumption. The HydroCal American Company conceived the cavitation air flotation (CAF) system [14] for industrial purposes, which includes efficient equipment and is simple and easy to maintain and operate.

The system consists of a parallelepiped tank (Fig. 3) divided into four main sections:

– Aeration room which contains the cavitation aerator;

– Flotation reservoir;

– Discharge channel of solid particles, with a scroll screw;

– Delivery pipe for cleared wastewater and an adjustable discharger.

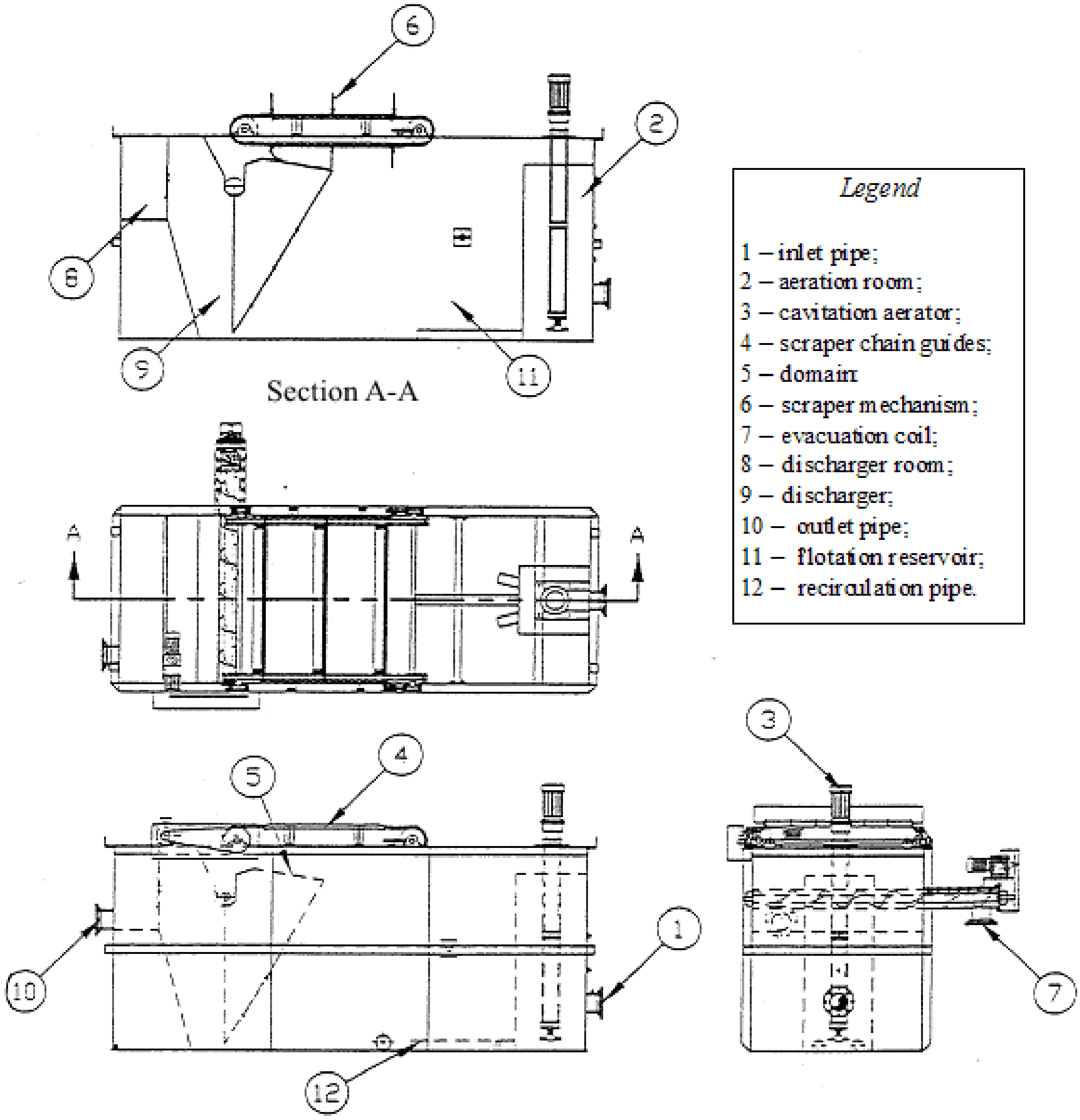

Fig. 3 Schematic diagram of the CAF system

The wastewater flows through the pipe (1) in the aeration room (2) where it is fixed by the cavitation aerator (3) and mixed

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with the produced micro-bubbles. The aerator then transfers the air from the water surface to a lower zone through the intake pipe. The density difference between the air-water mass and the liquid generates an upward flow of the realized mixture, which initiates the movement of the particles and leads them to the water surface. The ascension of particles in suspension is assured by the produced bubbles. Additionally, at the water surface, the air moves radially and pushes the particles.

The particles in suspension are periodically removed for cleaning by a scraper mechanism (6), which moves along the liquid surface. The scraper device has chains installed at both ends, and the chains are moved through a guide system (4). The scraper device moves along the entire width of the reservoir and transfers the suspensions from the surface into a metallic angular bowl for disposal in the discharge channel as sludge.

The discharge channel contains a horizontal coil screw (7) for suspension, to further move the solid particles away from the flotation reservoir in the collecting tank. The cleared wastewater flows through an immersed outlet in the room with a discharger (8) before being evacuated through the outlet pipe (10). The discharger (9) controls the liquid level in the floatation reservoir to block the liquid flow in the suspension discharge channel.

The recirculation pipes (12) have open ends that are radially dispersed in the aeration room along the foundation plate of the flotation reservoir. In addition, to produce the air bubbles, the cavitation aerator generates aspiration in the pipes. This phenomenon produces the recirculation of considerable volumes of liquid from the foundation plate of the reservoir towards the aeration room and back to the flotation reservoir. This action assures continuous flotation of reservoir content.

When the CAF system operates with the assistance of flocculation with chemical substances, there is a considerable reduction in the biochemical oxygen demand (BOD) and the chemical oxygen demand (COD) from the wastewater, thereby reducing the collecting costs. Solid suspensions (SS) are removed and stored separately in a concentrated shape, reducing the cost of sludge cleaning.

The CAF system is typically used in: the meat industry (for removing fat and solids from suspensions); the tanning industry (for sulphur oxidation and the removal of solid suspensions); the textile industry (for removing starch, fluff, and solid suspensions and dyes); slaughterhouses (for removing fat, grease, hair and solid suspensions); the alimentary industry (for removing fat, vegetal material and solid suspensions); city waste systems (for removing fat, grease and solid suspensions); and the paper industry (for clearing wastewater and removing fibres). The results for applications of the CAF system are summarized in Table 1.

The reported efficiencies are frequently above 90% for the removal of fat and oil, and the reduction in the percent of solid suspensions has a much greater value.

TABLE 1 PERFORMANCE OF THE CAF SYSTEM

Waste type	Flow rate [l/min]	Inlet			Outlet			Reduction		
		BOD [mg/l]	COD [mg/l]	SS [mg/l]	BOD [mg/l]	COD [mg/l]	SS [mg/l]	BOD [%]	COD [%]	SS [%]
Meat processing	1665	1440	–	3880	810	–	290	43.8	–	92.5
Chicken meat processing	833	510	–	395	120	–	36	76.5	–	90.8
Fish processing	946	2600	–	2500	1100	–	190	57.6	–	92.4
Food processing	2650	540	–	10,800	232	–	318	57.0	–	97.0
Cheese and milk processing	2498	–	44,400	6410	–	4800	334	–	89.1	94.7
Paper wastes	2498	–	9200	1780	–	4100	92	–	44.5	94.7
Desalting stations	833	–	–	3320	–	–	11	–	–	99.6

V. CONCLUSIONS

The local treatment of wastewater from isolated premises and industrial enterprises with private cleaning plants of reduced capacity may be assured by using relatively simple plants that are easy to build and operate. The cavitation air flotation system assures an economic method for removing fat, oils and solid particles in the wastewater produced by cities and industrial areas in a colloidal suspension. The recirculation degree provided by this system is much greater than that provided by the DAF system. The proposed solutions provide optimum conditions for public hygiene and health by avoiding the pollution of the water, soil and air within communities.

REFERENCES

[1] M A. Massoud, A. Tarhini, and J. A. Nasr, "Decentralized approaches to wastewater treatment and management: Applicability in developing countries", Journal of Environmental Management, vol. 90, pp. 652-659, 2009.

[2] T. Hedberg, "Attitudes to traditional and alternative sustainable sanitary systems", Water Science and Technology, vol. 39, no. 5, pp. 9-16, 1999.

[3] P. A. Wilderer, and D. Schreff, "Decentralized and centralized wastewater management: a challenge for technology developers", Water Science and Technology, vol. 41, no. 1, pp. 1-8, 2000.

DOI: 10.5963/JWRHE0403010

[4] P. A. Paraskevas, D. L. Giokas, and T. D. Lekkas, "Wastewater management in coastal urban areas: the case of Greece", Water Science and Technology, vol. 46, no. 8, pp. 177-186, 2002.

[5] I. Mirel, "Waste water treatment from isolated buildings", in Proceedings of the 2nd Symposium on Building Services and Ambient Comfort, Timisoara, Romania, April 1-3, pp. 102-107, 1993.

[6] I. Gruhler, "Mlasen inderungen a faul-und auafaulgruben vergenemmen werden", Wasserwirtschaft-Wassertechnik, vol. 3, pp. 28-34, 1981.

[7] H. Gueree, Practique de L'assainissament des Aglomerations Urbaines et Rurales, Paris, France: Eyrolles, 1965.

[8] M. Dima, Design of Purification Stations, Iasi, Romania: I.P. Iasi Publishing House, 1983.

[9] I. Sarbu, and O. Bancea, "Environmental protection assurance using efficient plants and procedures for sewage treatment", in Ecology, Economics, Education and Legislation, Proceedings of the 13th International Multidisciplinary Scientific GeoConference SGEM2013, Albena, Bulgaria, June 16-22, vol. 1, pp. 377-384, 2013.

[10] M. Benisch, R. Baur, O. R. Tigard, A. Britton, J. A. Oleszkiewicz, and J. B. Neethling, "Utilizing phosphorus recovery for optimization of the biological nutrient removal process", in Proceedings of the 2nd IWA Specialized Conference, Krakow, Poland, 6-9 Sept., pp. 1005-1015, 2009.

[11] H. M. Huang, X. M. Xiao, and B. Yan, "Recycle use of magnesium ammonium phosphate to remove ammonium nitrogen from rare-earth wastewater", Water Science and Technology, vol. 59, no. 6, pp. 1093-1099, 2009.

[12] I. Sarbu, "Efficient local waste water treatment plants", in Proceedings of First Ain-Shams Int. Conference on Environmental Engineering, Cairo, pp. 296-300, 2005.

[13] I. Sarbu, "Water treatment plant", Patent no. 100299, OSIM Bucharest, Romania, 1989.

[14] P. Finn, and N. Dvorak, Technologies and Treatment Plants HydroCal Bucharest: Kasta Servimpex 1996.

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