

PAPER • OPEN ACCESS

## Modernization of systems of air clearing in treatment facilities

To cite this article: E M Evsina *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **315** 052063

View the [article online](#) for updates and enhancements.

# Modernization of systems of air clearing in treatment facilities

**E M Evsina<sup>1</sup>, T V Alikova<sup>2</sup> and N V Zolotareva<sup>2</sup>**

<sup>1</sup> Department of Automated Design and Modeling Systems, Astrakhan State University of Architecture and Civil Engineering, 18, Tatishchev St., Astrakhan 414056, Russia

<sup>2</sup> Department of Analytic and Physical Chemistry, Astrakhan State University, 20a, Tatishchev St., Astrakhan 414056, Russia

E-mail: [evsinalena@mail.ru](mailto:evsinalena@mail.ru)

**Abstract.** New options are proposed for the modernization of existing air purification systems using know-how in the wastewater treatment plants themselves and in the area of their location. For air purification, it is proposed to use a new highly effective sorbent material, which is a claydite, covered with a thin layer of pyrolusite (manganese dioxide). This sorbent, which is in a wet state, oxidizes organic and inorganic toxicants on its surface, and also destroys pathogens. The proposed sorbent material is a natural formation obtained from the available raw materials approved for use for which additional permits are not required. Currently on the market there are no direct analogues of this product. Especially it is necessary to note a low cost of a new highly efficient sorbent material. In modern conditions, as a result of the increasing exploitation of water resources, the problems of human impact on the environment become particularly acute. These impacts, as a rule, are accompanied by factors that adversely affect the ecological state of the environment, both in the area of operation of the treatment facilities and in places far from them.

## 1.Introduction

New options are proposed for the modernization of existing air purification systems using know-how in the wastewater treatment plants themselves and in the area of their location. For air purification, it is proposed to use a new highly effective sorbent material, which is a claydite, covered with a thin layer of pyrolusite (manganese dioxide). This sorbent, which is in a wet state, oxidizes organic and inorganic toxicants on its surface, and also destroys pathogens. The proposed sorbent material is a natural formation obtained from the available raw materials approved for use for which additional permits are not required. Currently on the market there are no direct analogues of this product. Especially it is necessary to note a low cost of a new highly efficient sorbent material [1].

In modern conditions, as a result of the increasing exploitation of water resources, the problems of human impact on the environment become particularly acute. These impacts, as a rule, are accompanied by factors that adversely affect the ecological state of the environment, both in the area of operation of the treatment facilities and in places far from them. To solve this problem, the authors propose the following:

- carry out the work on the modernization of existing air purification systems using know-how in the wastewater treatment facilities themselves, and in the area of their location



- implement a pilot project that will increase investment attractiveness and eliminate risks from competitors.

The subject of design is the reconstruction of the system of southern sewage treatment facilities (SSTF) of the city of Astrakhan. SSTF serves the Sovetsky district, partly Leninsky and Kirovsky, that makes about 100,000 inhabitants, the number of users will grow [2].

The climate in the design area is moderate with high humidity. The average annual air temperature is 22.8 ° C. Maximum temperature is 42 ° C, minimum is 35 ° C. The coldest month is February, the hottest month is July. Soils are of sedimentary origin. The maximum depth of soil freezing is 0.9 m. The level of groundwater varies from 1.1 to 1.3 m.

## 2. Theoretical review

The southern sewage treatment facilities were commissioned in 1957 and are located in a flat area, with an artificial embankment to create gravity flow. The main structures include [3]:

- receiving chamber;
- horizontal sand traps;
- radial sump tanks;
- aerotanks;
- contact tanks.

In the process of urbanization, the residential area increased and approached the treatment facilities, thereby violating sanitary standards (see table 1).

**Table 1.** Sanitary standards for the location of treatment facilities.

Wastewater Treatment Facilities	The distance in m, with the estimated capacity of treatment facilities, thousand m <sup>3</sup> per day			
	up to 0.2	more than 0,2 up to 5,0	more than 5,0 up to 50,0	more than 50,0 up to 280
Pump stations and emergency control tanks	15	20	20	30
Mechanical and biological treatment facilities with sludge beds for digested sludge	150	200	400	500
Structures for mechanical and biological cleaning with thermomechanical treatment of sludge in enclosed spaces	100	150	300	400
Fields:				
a) filtration	200	300	500	1000
b) irrigation	150	200	400	1000
Biological ponds	200	200	300	300

Two factors influence the environmental safety of a design object:

- use of chlorine for sewage disinfection;
- unpleasant odor from primary radial septic tanks (formed in the process of biological treatment of wastewater from waste gases during the purification process, which are a mixture of smelly

recovered sulfur compounds — hydrogen sulfide, light mercaptans, nitrogen-containing organic substances, aromatic hydrocarbons, organic acids, ammonia, etc.) [4].

There are technical solutions that allow the use of ultraviolet radiation instead of chlorination. To solve the second problem (constant unpleasant smell), which has a direct, negative impact on the environment, the use of expensive technologies is proposed.

Installation of biological purification of waste gases generated in the process of biological wastewater treatment, consisting of a dropping biofilter "AZURAIR" with contact loading with immobilized microorganisms, irrigated by water with nutrients is known; the biofilter is equipped with a device for supplying water and a device for distributing the gas to be purified in the upper part of the body and with nozzles for discharging polluted water and purified gas - in its lower part [5].

A known system of biological purification of domestic wastewater and waste gases from the purification process is a mixture of foul-smelling compounds of reduced sulfur - hydrogen sulfide, light mercaptans, nitrogen-containing organic substances, aromatic hydrocarbons, organic acids, ammonia, etc. The system consists of a pump station with a receiving tank, receiving chamber of mechanical cleaning grids, sand trap, primary settling tank, aerobic stabilizer, anaerobic sediment digestion chamber, compaction units and both sedimentation, exhaust fan, exhaust gas pipeline, which ensures their discharge from the above system installations, equipped with an overlap, biofilter "Bioreactor TM" incoming air moisturiser, circulation water tank, deentrainment netting and air emission pipe [6].

We know a system of biological wastewater treatment and waste gases in the process of purification, including aerotank, secondary settling tank and ventilation device in the form of an inverted U-shaped tube, one of the branches of which forms a supply manifold, and the second one - with a vacuum degassing chamber located between them and a gas suction chamber built in it, connected to a vacuum source, for example, a suction pump [7].

The system of biological treatment of wastewater and waste gases in the process of purification is known. It consists of a receiving tank of a sewage pumping station, grate, sand trap, mixer - averager, primary clarifier, aerotank with recirculation sludge loop, pump, secondary illuminator, after-treatment filter, sludge treatment unit exhaust gas vent, biofilter, equipped with cassettes with a droplet separator adjacent to them, a spraying system, a tray for collecting the sludge mixture, as well as an intake pipeline sludge mixture and mixed liquor discharge pipe [8].

The system is also equipped with a fan exhaustor, an exhaust gas after-treatment adsorber, an installation of UV-disinfection of waste gases and a pipe to release the purified gas into the atmosphere [9].

The system of biological treatment of industrial wastewater and waste gases in the cleaning process is known. It includes sewage pumping station, gratings, sand traps, mixer - average, primary clarifier, aero tank with sludge recirculation pipeline, secondary clarifier, after-treatment filter, exhaust gas duct, exhaust fan, bio filter in the form of a cylinder with a ratio of height to diameter of 2: 1 for the purification of exhaust gases, equipped with a water circulation loop, and a pipe for the discharge of purified gases into the atmosphere.

### **3. Practical importance, implementation and results**

To solve this problem, the authors offer two versions [10].

#### *3.1. The first version*

As unpleasant odors are related to the functioning of the septic tanks, it is proposed to "cover" the septic tank and clean the dirty air. To solve this problem, it is proposed to build a dome and a reinforced concrete foundation on which this structure will be supported and fastened with bolts. The skeleton of the dome will be assembled by welding with the help of corners and I-beams and covered with sheets of cellular polycarbonate [11].

Cellular polycarbonate is a polymer profiled in two- or three-layer panels with internal longitudinal ribs, properties, and stability, which can be attributed to plastic materials of engineering class. The reasons for choosing a polycarbonate coating were its economic, technical characteristics.

In the designed structure (dome), a ventilation system is provided, which includes:

- five axial industrial fans;
- sensors (fan operation regulation);
- panels with new sorbent material located in front of the fan [12-14]

### 3.2. The second version

It is proposed to “cover” the sump and clean the dirty air. To solve this problem, it is proposed to build a roof (cylindrical form) and a reinforced concrete base over the settling tank, on which this structure will be supported and fastened with bolts. Filters (representing canisters of various shapes made of plastic, grids and legs for fixing canisters) are placed at the base of the cylinder and in the center of the cylinder. A new sorbent material is poured into the case [15-17].

Among the means of air purification of the working zone of industrial enterprises and in residential premises, various absorbers and engineering systems are used, among which active carbons, clays, expanded clay, oxide and calcium hydroxide, which are able to sorb and chemisorb acidic gases and vapors of organic substances on their surface. At present, separate sorption units are used to remove each of the listed toxicants. For air purification, it is proposed to use a new highly effective sorbent material, which is a claydite, covered with a thin layer of pyrolusite (manganese dioxide) [18-19].

This sorbent, which is in a wet state, oxidizes organic and inorganic toxicants on its surface, and also destroys pathogens. The proposed sorbent material is a natural formation obtained from the available raw materials approved for use for which additional permits are not required. Currently on the market there are no direct analogues of this product. Especially it is necessary to note the low cost of new sorbent material. Table 2 presents the advantages of a new sorbent material in comparison with other analogues on the purification of atmospheric air [20].

**Table 2.** Comparative characteristics of a new sorbent material with known analogues.

Characteristics of the developed sample, defining indicators	Characteristics of well-known national and foreign samples	Improvement of parameters or systems in relation to the best samples
Sorbent. Removal of sulfur dioxide $\text{SO}_2$ from atmospheric air Absorption time – 5 s. Bringing the content of $\text{SO}_2$ up to $0.01 \text{ mg/m}^3$ $\text{SO}_2 + \text{H}_2\text{O}_2 \rightarrow \text{H}_2\text{SO}_4$ $\text{H}_2\text{SO}_4 + \text{CaO} \rightarrow \text{CaSO}_4 + \text{H}_2\text{O}$ The non-toxic product calcium sulfate is formed	Special sorption installation is based on the absorption of sulfur dioxide by lime milk $2\text{SO}_2 + \text{Ca}(\text{OH})_2 \rightarrow \text{Ca}(\text{HSO}_3)_2$ Installation cost – 1500 thousand rubles., exploitation - 500 thousand. rubles / year Absorption time – 20 min.	When operating the installation with a new sorbent material, the installation using lime milk is not required.
Sorbent. Removal $\text{H}_2\text{S}$ from atmospheric air. Absorption time – 5 s. $\text{H}_2\text{S} + 2\text{H}_2\text{O}_2 \rightarrow \text{H}_2\text{SO}_4 + 2\text{H}_2\text{O}$ Bringing $\text{H}_2\text{S}$ content to $0.0001 \text{ mg/m}^3$ $\text{H}_2\text{SO}_4 + \text{CaO} \rightarrow \text{CaSO}_4 + \text{H}_2\text{O}$ The nontoxic product sulfate of calcium is formed	Special sorption installation based on absorption of hydrogen sulphide by soda $\text{H}_2\text{S} + \text{Na}_2\text{CO}_3 \rightarrow \text{NaHS} + \text{NaHCO}_3$ (sorption) When $\text{CO}_2$ is purged, $\text{H}_2\text{S}$ is desorbed: $\text{NaHS} + \text{NaHCO}_3 + \text{CO}_2 \rightarrow \text{H}_2\text{S} + \text{Na}_2\text{CO}_3$	When using a new sorbent material, installation with $\text{Na}_2\text{CO}_3$ is not required.

Further capture of H <sub>2</sub> S. Installation cost 1500 thousand rubles., exploitation - 500 thousand. rubles / year Adsorption-desorption time – 1 h		
Sorbent. Removal of nitric oxide NO and nitrogen dioxide NO <sub>2</sub> from atmospheric air $2\text{NO}_2 + \text{H}_2\text{O}_2 \rightarrow 2\text{HNO}_3$ $2\text{NO} + 3\text{H}_2\text{O}_2 \rightarrow 2\text{HNO}_3 + 2\text{H}_2\text{O}$ Contact time – 5 s. Final concentration of NO <sub>2</sub> и NO – 0,001 mg/m <sup>3</sup> $2\text{HNO}_3 + \text{CaO} \rightarrow \text{Ca}(\text{NO}_3)_2 + \text{H}_2\text{O}$ The nontoxic product sulfate of calcium is formed	A instalation in which NO is oxidized to NO <sub>2</sub> and N <sub>2</sub> O <sub>3</sub> with oxygen or reconstructed to elemental nitrogen (methane, CH <sub>4</sub> ). Catalysts are ruthenium, platinum, composites based on chromium, nickel, copper, zinc, vanadium, cerium. Process time – 1–10 s. Installation cost 1500 thousand rubles., exploitation - 500 thousand. rubles / year	When using a new sorbent material, a catalytic unit for the oxidation or reconstruction of NO is not required
Final conclusion		
For the sorption and oxidation of SO <sub>2</sub> , H <sub>2</sub> S, NO <sub>2</sub> , one installation is used with a total cost of 500 thousand rubles. Exploitation - 500 thousand rubles / year	The installation is used with a total cost of 1500 thousand rubles, Exploitation - 1500 thousand rubles / year	No need for three installations. The economic effect will be: due to the work of a single installation - 1000 thousand rubles, exploitation - 1000 thousand rubles / year

Table 3 presents the indicators for improving the quality of the created installation for cleaning unpleasant odors from primary radial sumps.

**Table 3.** Indicators of the quality of the sorbent.

Defining indicators	Parameters of quality improvement, %
Service life	10
Cleaning ability	45–50
Improvement of working conditions of the personnel of facilities	It has a social effect
Improvement of the ecological characteristic of facilities	to 50
The service life connected with stability in relation to external factors (wearability, corrosion stability)	20–25
Physical Data (Weight and dimension characteristics)	200

#### 4. Conclusions

The technical result of upgrading existing treatment facilities is:

- increasing the degree of purification of waste gases;
- the ability to reduce the sanitary protection zone of treatment facilities, and thereby ensure a more dense development of the territory;

- reduction in the cost of the system;
- simplification and improvement of the operating conditions of the system.

## References

- [1] Evsina E M and Alykov N M 2007 New sorption - filtering material for purifying atmospheric air of the working zone of industrial enterprises and in residential premises *Ecological systems and devices* **10** 35-6
- [2] Alykov N M and Evsina E M 2008 *Sorbent S-KP for purification of atmospheric air* Patent Russian Federation No 2336945 (Moscow: Rospatent) p 7
- [3] Antonov V V, Vdovenko L V, Popov P F, Poteskin A M, Tsurkov V D, Shapovalov S I and Shutov A A 1996 *Installation for the treatment of air supplied to the habitable compartment of the vehicle* Patent Russian Federation No.94017415 (Moscow: Rospatent) p 1
- [4] Zlotopolsky V M, Guzenberg A S, Krychenkov D A, Ereemeev S.I., Kutyev A A, Markin S V and Gavrilov L A 2001 *The method of air purification from harmful impurities and device for its implementation* Patent Russian Federation No.2161567 (Moscow: Rospatent) p 3
- [5] Saikin C A and Saikin A M 2006 *Method and device for air cleaning* Patent Russian Federation No.2319622 (Moscow: Rospatent) p 13
- [6] Singh R, Khwaja A R, Gupta B and Tandon S N 1999 Quaternization of poly (4-vinyl pyridine) beads with 2-chloroacetamide for selective mercury extraction *Talanta* **48** 527-35
- [7] Dakshinamoorthy A, Kumar T, Nandy K K, Iyer R N, Mathur J N and Manohar S.B. 2000 Microspherical Carriers and Adsorbents for the Processes in Corrosive Media *Radical. Nucl. Chem.* **245(3)** 595-8
- [8] Tranter T J, Herbst R S, Todd T A and Olson A L 2002 Eldredge Removal of Cs-137 from Acidic Nuclear Waste Solutions *Adv. Env. Res.* **6** 107-121
- [9] Alykov N.M., Evsina E.M., Eysin A.M. 2013 *Sorbent for removal of air from the water vapor, acid gases and microorganisms in the salons (booths) of vehicles and premises* Patent Russian Federation No. 2473383 (Moscow: Rospatent) p 5
- [10] Alykov N M, Alykov N N., Alykova T V, Sadomtsev K Yu, Voronin N I and Klyayev V I 2005 *Flasks of Astrakhan region* (Astrakhan: Astrakhan State University) p 139
- [11] Evsina E M, Alykov N M, Kudryashova A E, Eysin A M, Ermilova T O and Alykov N N 2014 New sorbent for removal of air from the water vapor, acid gases and microorganisms *Ecology and Industry of Russia* **8** 17-20
- [12] Kasatkin A G 2004 *Basic processes and devices of chemical technology* (St. Petersburg: Chemistry) p 137
- [13] Baron N M 1974 *Handbook of physical-chemical variables book* (Leningrad: Chemistry) p 338
- [14] Stockman E A 1998 *Air Purification* (Moscow: DIA) p 225
- [15] Kostryukov V A 1965 *Digest of examples of calculating for heating and ventilation* (Moscow: Gostroyizdat) p 132
- [16] Alykov N M and Evsina E M 2007 United mathematical model of the processes of diffusion, sorption and chemical kinetics to describe the processes of the chemisorption *Ecological systems and devices* **10** 55-6
- [17] Alikova T V and Alykov N N 2002 Methods for determination of phenols in environmental objects after their concentration on the sorbent S-1 *Natural Sciences* **5** 183-91
- [18] Ahrens V Zh and Gridin O M 1997 Effective sorbents for the elimination of oil spills *Ecology and industry of Russia* **4** 32-7
- [19] GOST R 54655- 2011 *Editions. National standard of the Russian Federation* (Moscow: Standartinform) p 25
- [20] Mtsiaryashvili M R, Portnova S V, Egorova S N and Garmonov S Yu 2016 Development of a method for chromatographic determination of hydrocortisone, nipagin and its validation *Bulletin of the Kazan Polytechnic University* **8** 168-71