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UTILIZATION OF THE WASTES OF VITAL ACTIVITY

B. G. Gusarov, et al

Translation of "Utilizatsiya otkhodov zhiznedeyatel'nosti,"
in Problemy sozdaniya zamkhutykh ekologicheskikh sistem
[Problems of the Creation of Closed Ecological Systems],
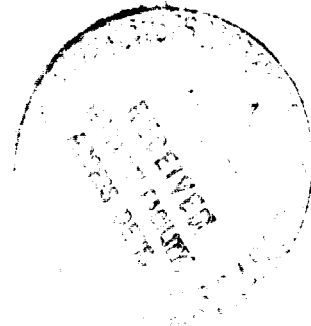Moscow, Nauka, 1967, pp. 141-170

1. Report No. NASA TM-75410	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle UTILIZATION OF THE WASTES OF VITAL ACTIVITY		5. Report Date February 1979
		6. Performing Organization Code
7. Author(s) B. G. Gusarov, et al		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address Leo Kanner Associates Redwood City, California 94063		11. Contract or Grant No. NASw- 3199
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Admin. Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Translation of "Utilizatsiya otkhodov zhiznedeyatel'nosti," in Problemy sozdaniya zamknutykh ekologicheskikh sistem [Problems of the Creation of Closed Ecological Systems], Moscow, Nauka, 1967, pp. 141-170

16. Abstract

These articles discuss the recycling of wastes from the biological complex for use in life-support systems. Topics include laboratory equipment, heat treatment of waste materials, mineralization of waste products, methods for production of ammonium hydroxide and nitric acid, the extraction of sodium chloride from mineralized products and the recovery of nutirent substances for plants from urine.

17. Key Words (Selected by Author(s))	18. Distribution Statement Unclassified-Unlimited		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 49	22. Price

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UTILIZATION OF THE WASTES OF VITAL ACTIVITY

THE PROBLEM OF CREATING LABORATORY INSTALLATIONS
FOR A UTILIZATION UNIT

B. G. Gusarov, Yu. A. Drigo, V. M. Novikov, N. M. Samsonov,
N. S. Farafonov, S. V. Chizhov and V. I. Yazdovskiy

The utilization unit is one of the most important and com- /141*
plex parts of a life-support system created in a closed, limited
space, based on the partial or complete recycling of substances
[1-3]. Under these conditions, the utilization unit is a quali-
tatively new element which replaces a large number of functioning
natural units with a limited number of processes providing re-
processing of the products of human vital activity and the acti-
vity of the biological complex at a definite rate of circulation
of the substances produced [3, 4]. Tnerefore, developing the
utilization unit presents definite theoretical and technical dif-
ficulty.

This article presents data on the first attempts to construct
laboratory installations for individual utilization units based
on preliminary investigations conducted previously on certain
processes of the physical and chemical reprocessing of products
of human and biocomplex vital activity.

The installation for utilization and separation of gases is
intended for investigating processes of the recovery of gaseous
products produced in various parts of the utilization unit. Its
overall appearance is shown in fig. 1.

The mixture of gaseous products enters a furnace unit con-
sisting of electric heating elements and a reactor. The gas and

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* Numbers in the margin indicate pagination in the foreign text.

air mixture can be heated to 500°C in electric heaters with automatic temperature regulation. The heated mixture enters the reactor, which is filled with a catalyst. As a result of the high temperature and the effect of the catalyst, oxidation of individual components of the gas and air medium under investigation occurs. The selectivity of oxidation of the components is determined by the type of catalyst and the temperature conditions. The oxidation of CO, H_2S and NH_3 can occur in the reactors with the formation of CO_2, water vapor and various oxides of sulfur and nitrogen.
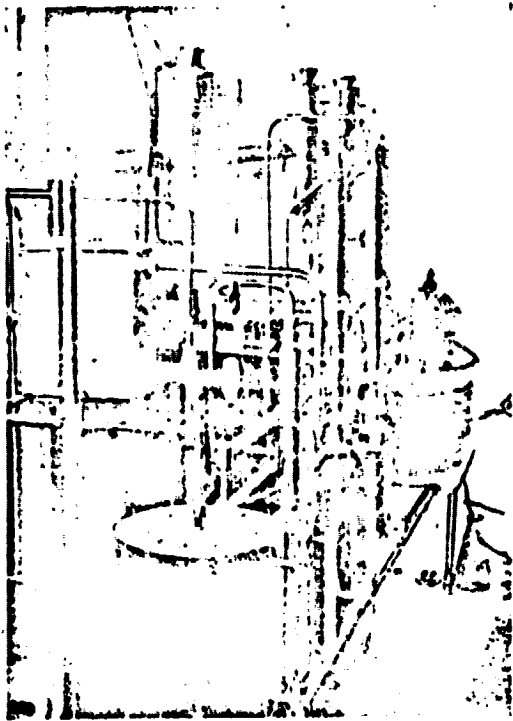
Fig. 1. An overall view of the installation for utilization and separation of gases

Subsequently the gas mixture passes from the reactor through an air cooler into adsorption columns, where selective absorption of individual oxides occurs. The selectivity of absorption is conditioned by the type of sorbents and the temperature conditions of the sorption process.

In preventing individual components of the gas and air medium under investigation from "getting through," the medium is repeatedly channeled into the catalytic furnace for accomplishing the process of complete combustion. After saturation of the sorbents in the adsorption columns, regeneration is performed. The product is collected in collecting tanks, from which it is sent for subsequent use.

The installation for preparing nutrient solutions is intended for producing media suitable for higher and lower plants from the mineralized products of human and biocomplex vital activity by using the process of chromatographic separation and oxidation under high temperature and pressure conditions. An overall view of the installation is shown in fig. 2.
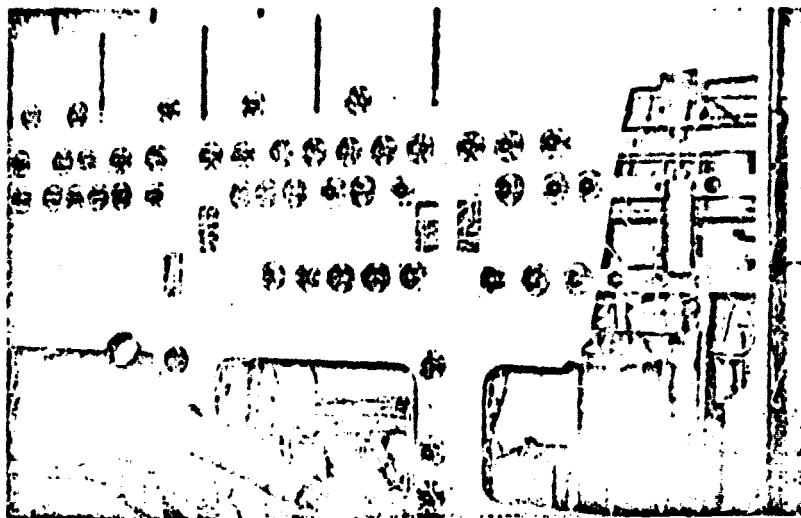
Fig. 2. An overall view of the installation for preparation of nutrient solutions

The initial product is fed into a tank where it is diluted with distilled water and carefully agitated. The mixture produced is channeled first into a homogenizer for producing a finely dispersed suspension and then into an autoclave, where heavy metal hydroxides are extracted, and the organic substances are oxidized under high pressure and substantial temperatures. The liquid passes from the autoclave after cooling into a filter pump, and the residue obtained is dissolved in nitric acid and passes into a collector for storage of inorganic salt solutions. The filtered solution is fed through a heat exchanger into chromatographic columns, where Na, K, Ca and Mg cations and SO_4, PO_4 and Cl anions are absorbed. After the chromatographic columns, the solution is collected in a receptacle which also acts as an

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evaporator, from which the vapors are channeled through a vapor heater into the catalytic furnace. After the catalytic furnace, the condensate and the uncondensed gases are collected separately and directed for subsequent use.

As a result of regeneration of the chromatographic columns, the separation of cations and anions used for preparation of nu- /144 trient solutions is accomplished in special receptacles.

The installation for water regeneration by the lyophilic method is intended for developing the technical conditions for obtaining water from liquid products of human and biocomplex vital activity.

The initial product is fed into an evaporator and frozen. After freezing of the product, a vacuum is created in the installation. The sublimation components of the source product pass into a condenser, where selective freezing out of individual components occurs, depending on the temperature conditions. The frozen components are warmed and passed on for later use.

Preliminary investigations performed on the equipment indicated above confirmed the theoretical possibility of constructing a utilization unit. However, in order to develop experimental (flight) models of installations for individual sections of the utilization unit, the following work must be done:

1. Research to study the physical and chemical processes of reprocessing of the products of human and biocomplex vital activity.

2. The development of improved designs for experimental installations.

3. Research to study the toxicity of the materials used.

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THE CONSTRUCTION OF A UNIT FOR HEAT TREATMENT OF WASTES IN A LIFE-SUPPORT SYSTEM BASED ON RECYCLING OF SUBSTANCES

B. A. Balin, B. L. Gol'dshchvend, L. B. Zarudnyy,
A. G. Lobanov, V. A. Pechurkin, G. S. Sinyak and S. N. Shorin

High temperature combustion is one of the methods for mineralizing the products of human and plant vital activity. This method makes it possible to convert the products of vital activity into extremely simple inorganic compounds, gaseous and solid, which are the raw material for the preparation of nutrient media for higher and lower plants.   /145

It is assumed that the products subject to combustion in a closed system for matter recycling will consists primarily of solid wastes of human and plant vital activity (feces, plant tops, cooking wastes). From the point of view of heat engineering, these substances should be classified as belonging to the group of raw organic fuels. A high oxygen concentration (up to 45%), a high yield of volatile products (80 to 85%) and high porosity of the coke residue are characteristic of the combustible mass of these fuels. In their natural form, the indicated wastes are characterized by a high moisture content (80 to 95%), which sharply reduces the heat of combustion and makes it impossible to consider them fuel material in the normal sense.

The concentration of mineral ash residue in relation to the dry mass amounts to from 1-2% in the plant waste to 10-12% in the fecal waste.

Since the process of carbon combustion is basic to the combustion of solid fuel [1], this work devotes special attention to evaluation of the reaction properties of the coke residue of the wastes of vital activity. It follows from comparison of the compositions and most important thermotechnical characteristics of

normal organic fuels to the corresponding characteristics of human and plant vital activity wastes that a mixture of wastes should occupy an intermediate position between wood and peat. The pattern noted makes it possible to use the known characteristics of the reactive gas exchange constant for charcoal and peat coke in evaluating the reaction properties of the waste mixture coke residue [1]. A corresponding analysis has been performed for the temperature range of 600-950°C which is of interest in this case in regard to the combustion of ground (to 0.1-0.5 mm) wastes of vital activity.

This analysis, based on comparison of the reactive gas exchange constant and the coefficient of mass transfer of the oxidizer to the surfaces of burning particles, indicated that the combustion process will occur in a kinetic or intermediate chemical reaction range. Therefore, ensuring an adequate duration of the presence of the product under combustion in the combustion chamber should be considered essential in organizing the combustion flow scheme, while physical factors for intensification of the process (the oxidizer rate, particle dimensions, etc.) should be considered only as auxiliary measures.

Based on preliminary theoretical and experimental investigations of a number of different alternative designs of combustion chambers, the following can be recommended as designs in which the indicated features of the vital activity waste combustion process can be realized with the greatest success: /146

a) cyclone reactors for burning a preliminarily dried and ground product;

b) a reactor operating according to a concentrated combustion zone scheme for burning a raw product with a moisture content of 70-80%.

In connection with the extremely low heating capacity of the combustion unit, the temperature level which is necessary in regard to the combustion conditions can be provided (without a heat supply from a constant source) only by deep heat regeneration and the creation of efficient, nearly adiabatic thermal insulation.

Research on the burning of vital activity wastes in combustion chambers of various designs and testing of alternative designs of auxiliary elements of the combustion unit were performed on a general-purpose laboratory testing unit, a diagram of which is presented in fig. 1. The laboratory installation consists of the following main elements: an electric power system, a dry and wet fuel feeder system, a system for feeding air and removing combustion products, a system for dust removal and cooling of the combustion products, and monitoring measurement and registration instruments for measuring the pressures, temperatures, flows and compositions of exhaust gases and analyzing the source product and the ash residue. The central element of the laboratory installation is a removable combustion chamber (1) enclosed in an electrical furnace (14), which is intended for compensation for heat losses into the surrounding space and which plays the role of high temperature thermal insulation.

The experimental investigation performed on several alternative cyclone furnace designs, as one of the types of furnace devices in the overall scheme which has been developed for burning the wastes of vital activity, had the purpose of discovering the efficiency of their operation, i.e., of evaluating the chemical and mechanical incompleteness of combustion depending on conditional factors and certain structural characteristics, and investigating the possibility of continuous ash removal from the combustion chamber. The volumetric heat load, the granulometric composition of the fuel, the air surplus coefficient, the temperature of the process and the rate of injection of secondary air

were adopted in the experiments as variable conditional factors. The following conclusions can be drawn from the results of these experiments.

1. The cyclone principle, in concrete form in the designs of miniature chambers tested in this work, can be considered satisfactory from the point of view of continuity of the process of fuel combustion and removal of hearth residue.

2. The efficiency of combustion chamber operation (determined in regard to the level of chemical and mechanical incompleteness of combustion) depends quite clearly on such conditional factors as the temperature of the process, the air surplus coefficient, the rate of injection of secondary air and the proportion of primary air. /148

3. Of the cyclone furnace designs investigated, a furnace with an afterburner proved best.

A scheme of concentrated combustion zones, in contrast to the well-known cyclone principle [2, 3] adopted for mineralization of dried and ground wastes, is suggested for burning a product with a high moisture content. In this case, a zonal process of carbon oxidation and partial burning out of carbon monoxide and other light substances is accomplished in the layer of the mass of matter in the reactor by convective diffusion transfer of oxygen. In contrast to blasting of the layer with an oxidizer medium, convective diffusion oxygen transfer into the layer avoids a producer process of carbon dioxide reduction, which reduces the temperature of the layer. Experience demonstrates that the temperature in the layer exceeds the temperature in the surrounding atmosphere of the reactor. Therefore, one can assume that in convective diffusion transfer of oxygen into the layer, the combustion process in it is intensified.
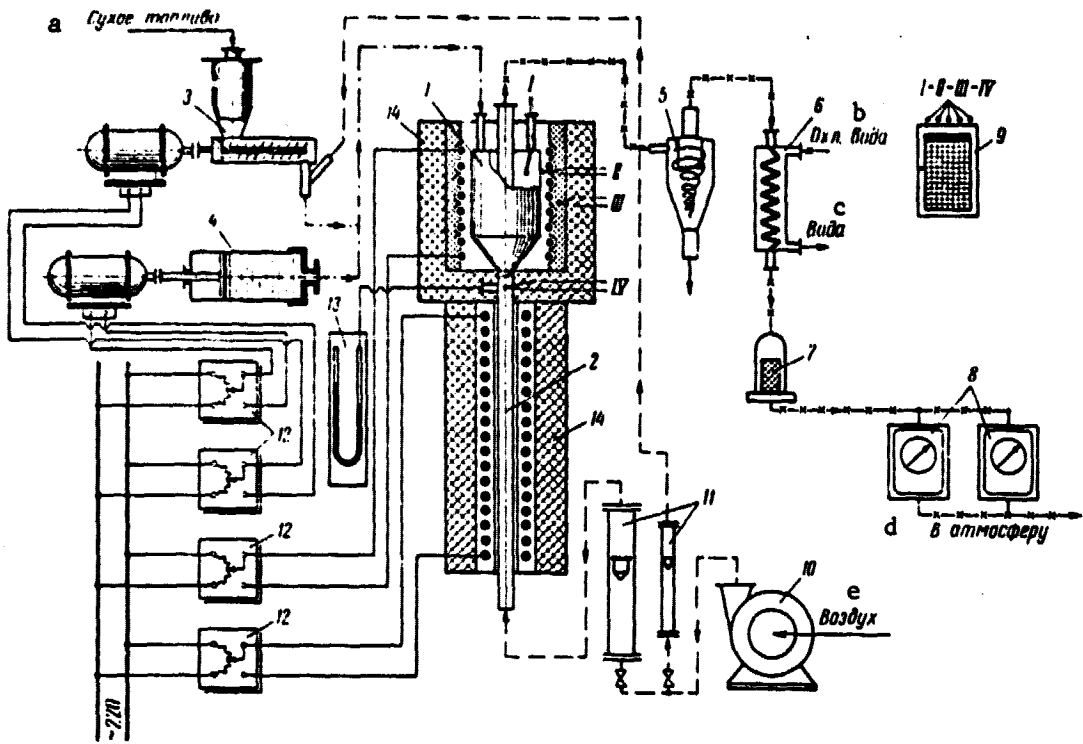
Fig. 1. A diagram of an experimental installation for burning the wastes of vital activity. Key: 1 - combustion chamber; 2 - air heater; 3 - dry product feeder; 4 - high-moisture product feeder; 5 - cyclone ash trap; 6 - cooler; 7 - fine purification ash trap; 8 - gas analyzer; 9 - electronic multipoint potentiometer; 10 - blower; 11 - rotameter; 12 - laboratory autotransformer; 13 - manometer; 14 - electrical furnace; I-IV - thermocouples; a - dry fuel; b - coole water; c - water; d - to the atmosphere; e - air

At the layer interface with the surrounding atmosphere of the reactor, we have the following equality for any moment in time τ:

$$\alpha_{O_2,F}(C_{O_2,\infty}-C_{O_2,F})=D_{O_2}\frac{\partial C_{O_2}}{\partial n}\bigg|_{F_1\tau_1-n}+q_{O_2,\text{conv},\tau}, \qquad (1)$$

where $\alpha_{O_2,F}$ is the mass transfer coefficient at the layer surface, $C_{O_2,F}$ and $C_{O_2,\infty}$ are the oxygen concentrations at the layer surface and in the reactor space, D_{O_2} is the oxygen diffusion

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coefficient, $\left.\dfrac{\partial c_{O_2}}{\partial n}\right|_{F_1 \tau_1 - n}$ is the oxygen concentration gradient in the layer at the surface at the moment in question, and $q_{O_2, conv, \tau}$ is the convective transfer of oxygen into the layer.

The specific oxygen transfer flow into the layer,

$$-D_{O_2} \left.\frac{\partial c_{O_2}}{\partial n}\right|_{F_1 \tau_1 - n} + q_{O_2, conv, \tau},$$

depends on the time, since the resistance to transfer from the burned out layer increases constantly. However, a simultaneous increase in the thermal resistance leads to an increase in the temperature in the layer and an increase in combustion intensity.

The following equation can serve for approximate evaluation of the reaction front temperature in the layer:

$$\alpha_T (T_F - T_a) = \frac{T_{fr} - T_F}{R_T(\tau)} ; \tag{2}$$

from this we have the proportion:

$$\frac{T_{fr}}{T_F} = 1 + \alpha_T R_T(\tau)\left(1 - \frac{T_a}{T_F}\right), \tag{3}$$

where T_{fr}, T_F and T_a are the temperatures of the combustion front in the layer, the layer surface and the surrounding atmosphere of the reactor, α_T is the heat transfer coefficient, and $R_T(\tau)$ is the thermal resistance of the burned out layer at the moment in question.

A graphic illustration of the qualitative picture of the concentration and temperature distributions in convective diffusion oxygen transfer in a burning layer is presented in fig. 2. The position of the front (shown conditionally as planar) corresponding to different moments in the course of the process is designated in the figure by dotted lines I, II, etc.
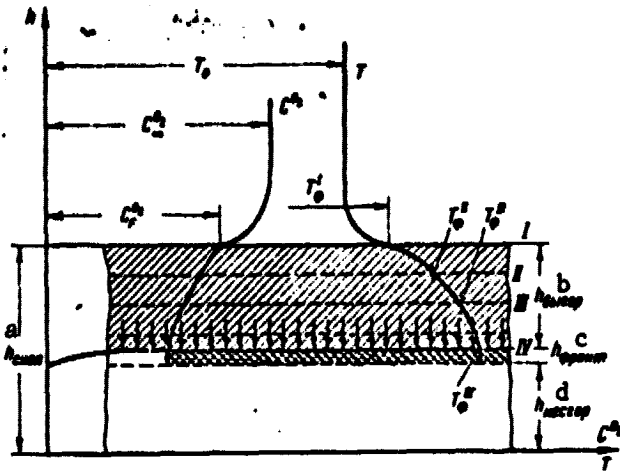
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Fig. 2. The distribution of the oxygen concentration ($C^{O}2$) and the temperature (T) in the layer under convective diffusion oxygen transfer. Key: a – h_{layer}; b – $h_{burn\ out}$; c – h_{front}; d – $h_{unburned}$

The oxidizer concentration drops somewhat and the temperature increases in proportion to the penetration of the reaction front into the layer:

$$T_{fr}^{IV} > T_{fr}^{III} > T_{fr}^{II} > T_{fr}^{I}.$$

Such a localization of the high temperature in the layer renders organization of the combustion process at low temperatures of the gas medium in the reactor more profitable. If the layer were blasted with the entire surrounding atmosphere in the reactor, as is done in normal grate-fired furnaces, the theoretical combustion temperature would be lower than the localized temperature in the layer in convective diffusion oxygen transfer in the layer.

The indicated features are the bases of the efficiency of the scheme suggested for organization of the combustion process in the reactor.

Experimental testing of the method in question for burning vital activity wastes with high moisture contents confirmed the existence of the picture examined above for the temperature distribution in the layer. In experiments with combustion zones of 5 and 10 g, the temperature in the layer exceeded the temperature in the reactor space by about 100°. Experiments also demonstrated that in organization of the process according to the scheme in

question, it is possible to accomplish sufficiently effective· combustion of wastes with high moisture contents at relatively low temperatures in the volume of the combustion chamber. For example, at a temperature in the chamber volume t_c=500°C, the concentration of combustible materials in the ash amounted to 2.75%; the concentration was 0.85% at a temperature of 700°C. The ash residue was in the combustion chamber for 45 minutes after completion of the intensive combustion stage in these ex- periments.

Trial experiments on the dissolution of the ash residue in nitric acid demonstrated that the maximum solubility of the ash amounted to 87%.

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MINERALIZATION OF PRODUCTS OF HUMAN AND PLANT VITAL ACTIVITY BY THE WET COMBUSTION METHOD

Yu. A. Drigo, V. M. Ivanov, S. O. Kuznetsov, V. M. Novikov, Yu. Ye. Sinyak, V. N. Trukhachev and N. S. Farafonov

The construction of a life-support system based on recycling substances in a closed volume requires the development of a utilization unit. The main purpose of the utilization unit is the transformation of all products of vital activity into substances which can be used by man, plants or animals [1].

One of the possible designs of the utilization unit in- /151 cludes three main sections: mineralization, reprocessing of gaseous compounds, and preparation of nutrient solutions.

The necessity of mineralization (oxidation) is dictated by the difficulty of using unprocessed products of vital activity in limited spaces in conducting intensive cultivation of autotrophs. The main obstacle is the presence of organic compounds which cannot be directly assimilated by the plants and can even inhibit their growth [2]. With transformation of the organic component into carbon dioxide, water, sulfates, nitrates or ammonia, mineralization of vital activity products should lead to the production of gases and a solution of mineral salts.

One of the possible methods for physical and chemical mineralization is the wet combustion method, the essence of which lies in oxidation of vital activity products with air oxygen in a liquid phase (water) under high pressures [3-6]. The first works on the use of the wet combustion method for processing waste water [3, 4] indicated that at temperatures of 200-300°C and pressures of 50-150 technical atmospheres, up to 80% of the organic matter contained initially is oxidized. The gas phase in this

process contains carbon dioxide and molecular nitrogen primarily with small admixtures of saturated hydrocarbons and hydrogen. In addition, a substantial quantity of ash is precipitated.

However, the use of mineralized solutions containing less than 20% unoxidized organic compounds can lead to undesirable effects in plant cultivation. In addition, the release of molecular nitrogen from nitrogen-containing products of vital activity requires the development of a nitrogen fixation unit. The lack of published data on the chemical compositions of mineralized liquid and solid phases makes it impossible to draw a conclusion concerning the possibility of using vital activity products processed by the method indicated above for plant cultivation.

This work has attempted to investigate the possibilities for conducting the mineralization process by the wet combustion method with the maximum possible preservation of all mineral salts in the liquid phase.

A device was constructed for studying these problems; a diagram of the device is shown in fig. 1.

Homogenized products of vital activity passed through a funnel (1) into an autoclave (2) with a capacity of 1 ℓ. Air was forced through a valve (a) into the autoclave until the necessary pressure was achieved. After closing of the valve, electric heating of the autoclave was initiated; as a result, the temperature and pressure increased to the levels necessary for conducting the oxidation reaction. After the end of the process, the mineralized solution passed through a valve (c) into the condenser (3) <u>/152</u> and then into the collector (4). The pressure was measured with a manometer (5), and heat regulation and registration of the temperature were performed with an EPV-2 electronic self-recording instrument (6).
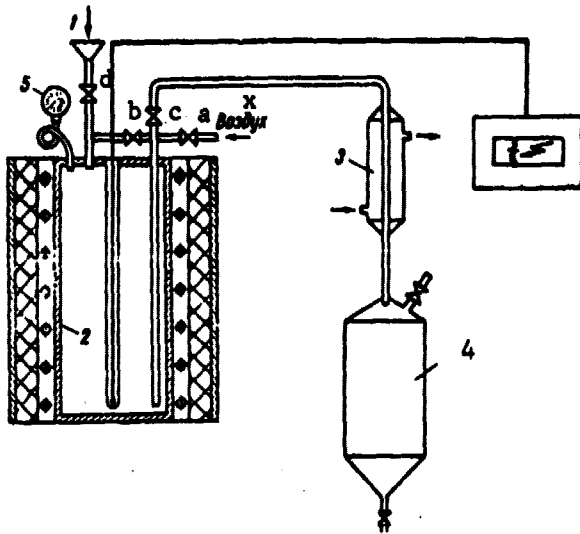
Fig. 1. A diagram of a unit for mineralization of products of vital activity by the wet combustion method. Key: x - air

The following products of vital activity and of the biological complex were subjected to mineralization by the wet combustion method: urine, feces, chlorella.

The source products and the final mineralized media were analyzed in regard to the same indices by identical procedures [7-10] for determining the efficiency of the wet combustion method. The quantity of organic matter was determined according to bichromate oxidizability, organic nitrogen was identified by the Kjeldahl method, nitrite nitrogen by the Griss method, nitrate nitrogen by the sulfosalicylic or sulfophenol method, with subsequent colorimetry on an FEK-M photoelectric colorimeter, and ammonia nitrogen colorimetrically with a Nessler reagent. Potassium and sodium ions were determined by the flame photometry method. The calcium concentration was measured by complexone measurement with Trilon-B at a pH of 12 in the presence of a chrome dark blue indicator. The iron concentration was determined in an alkaline medium with sulfosalicylic acid, with subsequent colorimetry. The concentration of phosphorus was measured with ammonium molybdate, with subsequent colorimetry, and with parallel titrometric measurement with lanthanum nitrate. Chlorides were determined by the Volgardt method with silver nitrate. Analysis of the gas /153

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was conducted by the volumetric method by means of a VTI gas analyzer.

The first series of experiments was performed at high values of the parameters of the process: a temperature of 300°C and an initial air pressure in the autoclave of 50 technical atmospheres. The mixture of urine and feces entering the autoclave was made up of 75-150 mℓ urine, 20-40 g fecal matter and 400 mℓ water. The results of experiments on mineralization conducted under these conditions are presented in table 1. For comparison, the table shows the chemical compositions of standard nutrient solutions used for cultivation of lower (the Tamiy medium) and higher (the Knop medium) plants.

One can see from the table that the efficiency of mineralization amounts to 90-95% in this variant of the experiment.

The solution produced as a result of mineralization by the wet combustion method is a clear liquid. The urine-fecal odor of the solution disappears as a result of mineralization, and a weak odor of an indefinite character remains. When the solution is allowed to stand, a white sediment is deposited.

The presence of nitrogen in the form of ammonia in the li- quid phase is an interesting feature of the mineralized solution.

The chemical composition of the gas phase produced as a result of mineralization of urine-fecal mixtures by the wet combustion method is presented in table 2, from which it follows that the gas phase consists primarily of nitrogen, carbon dioxide and residual oxygen. The concentrations of carbon monoxide and hydrogen sulfide lie outside the limits of sensitivity of the volumetric method. However, the presence of small amounts of saturated hydrocarbons and hydrogen is detected in the gas phase.

TABLE 1 - THE CHEMICAL COMPOSITIONS OF MINERALIZED URINE-FECAL
SOLUTIONS AND STANDARD GROWTH MEDIA

1 Химический состав, мг/л	Минерализованный раствор 2	3 Среда Кнопа	4 Среда Тамия
5 Азот общий	1700	153.3	700
6 Азот аммиака	1600	0	0
7 Азот нитратов	1	153.3	700
8 Азот нитритов	0	0	0
9 Калий	390	168	2250
10 Фосфор	32	57.0	285
11 Кальций	18	169.5	0
12 Железо	2—3	1.2	3
13 Хлориды	3000	2.2	0
14 Магний	18—24	24.7	240
15 Сера	660	32.4	320
16 Окисляемость исходная, мг O₂/л .	20 000—50 000	—	—
17 Окисляемость конечная, мг O₂/л .	1400—4000	—	—
pH	6.3—9.2	—	—
α*, %	92÷93	—	—

*α is the mineralization coefficient, calculated according to the
formula α=(Aorg-Acon)/Aorg·100%, where Aorg is the quantity of or-
ganic matter in the initial solution, and Acon is the quantity of
organic matter remaining after mineralization. Key: 1 - chemi-
cal composition, in mg/ℓ; 2 - mineralized solution; 3 - Knop me-
dium; 4 - Tamiy medium; 5 - overall nitrogen; 6 - ammonia nitro-
gen; 7 - nitrate nitrogen; 8 - nitrite nitrogen; 9 - potassium;
10 - phosphorus; 11 - calcium; 12 - iron; 13 - chlorides; 14 -
magnesium; 15 - sulfur; 16 - initial oxidizability, in mg O₂/ℓ;
17 - final oxidizability, in mg O₂/ℓ

It was also of interest to trace the dynamics of variation
of the degree of mineralization of vital activity products de-
pending on the duration of the combustion process, with the other
conditions of the experiment kept constant. The results of the
experiment are shown in fig. 2.

The character of the curve obtained indicates that the pro-
cess of mineralization of urine-fecal mixtures by the wet com-
bustion method is characterized by high rates of oxidation in
the first hours of the process, with a slight subsequent increase.

Under the actual conditions of functioning of the minerali-

TABLE 2 – THE CHEMICAL COMPOSITIONS OF GASES FORMED IN MINERALI-
ZATION OF A URINE-FECAL MIXTURE BY THE WET COMBUSTION METHOD

Компоненты газовой смеси 1	Количество отдельных компонентов (объемные %) 2	Компоненты газовой смеси 1	Количество отдельных компонентов (объемные %) 2
CO$_2$	6—7	CO	Не обнаружено 4
O$_2$	8—13	3 H$_2$S	» » 5
N$_2$	79—80	Предельные угле-	0,3—0.7
H$_2$	0.5—0.7	водороды	

Key: 1 – gas mixture components; 2 – quantities of individual
components (in % by volume); 3 – saturated hydrocarbons; 4 – not
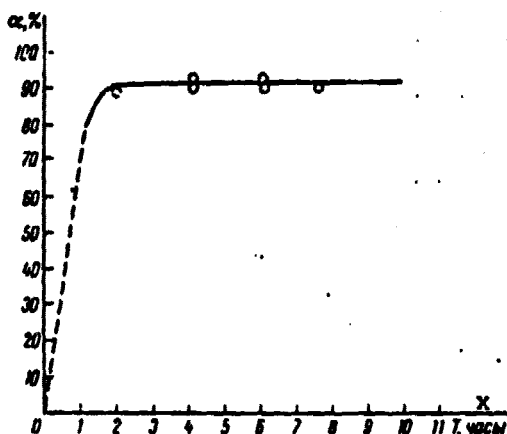detected; 5 – not detected

Fig. 2. The dependence of the
mineralization coefficient (α)
of vital activity products on
the time for conducting the
wet combustion process. Key:
x – time, in hours

zation unit, accomplishing
this process at a low tempera-
ture and pressure takes on
definite importance. Experi-
ments conducted for this pur-
pose have demonstrated the
possibility of oxidation of
vital activity products with
a substantial reduction in
these parameters. The results
of mineralization of urine-
fecal mixtures at two tempera-
ture levels (220 and 320°C)
and various pressure conditions
in the autoclave during combus-
tion (the initial pressure was

10 technical atmospheres in both cases, and the final pressures
were 50 and 80 technical atmospheres, respectively) are presented
in fig. 3.

One can see that 70-80% mineralization was achieved in this
variant of the experiment.

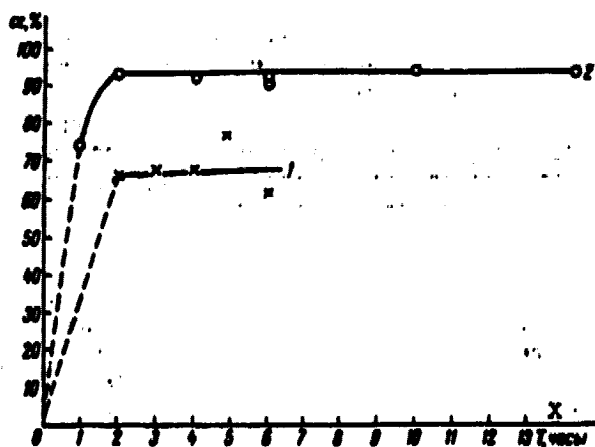The solution produced as a result of mineralization of the

Fig. 3. The dependence of the mineralization coefficient (α) for vital activity products on the duration of combustion at low values of the parameters of the process. 1 - initial pressure, 10 technical atmospheres; final pressure, 50 technical atmospheres; temperature, 220°C; 2 - initial pressure, 10 technical atmospheres; final pressure, 80 technical atmospheres; temperature, 320°C. Key: x - time, in hours

products of human vital activity by the wet combustion method is characterized by high pH values (~9). This is conditioned by the release of ammonia in urine hydrolysis, leading to alkalization of the medium and precipitation of calcium and magnesium phosphates.

For preventing the /156 passage of individual elements into the precipitate, the mineralization process should be repeated in an acidic medium. Acidification can be accomplished with nitric acid produced from ammonia by the catalytic method [11] in urine hydrolysis. Experiments conducted on the mineralization of urine-fecal mixtures with the use of nitric acid revealed the possibility of preserving practically all salts in the liquid phase.

It follows from table 1 that the mineralized solution contains chlorides (primarily NaCl) in quantities exceeding the acceptable concentrations. A sharp increase in the NaCl concentration will be observed in repeated use of the nutrient solutions. Consequently, for stable functioning of the matter recycling system, a sodium chloride extraction unit is necessary.

Basic experiments on the cultivation of higher plants re-

vealed the possibility of using mineralized solutions as growth
media. However, the residual quantity of organic matter does
not yield an unequivocal conclusion concerning the possibility
of long-term use of mineralized urine-fecal solutions for
plant cultivation.

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PHYSICAL AND CHEMICAL METHODS FOR PRODUCING AMMONIA WATER AND NITRIC ACID FROM THE WASTES OF HUMAN VITAL ACTIVITY

M. I. Belyakova and Yu. Ye. Sinyak

The need of both higher and lower plants for ammonia water and nitric acid makes it necessary to produce these substances. In addition, nitric acid is needed for correction of the pH of nutrient solutions, for dissolving salt deposits produced in insoluble form in wet combustion, for dissolving ash produced in thermal combustion of the wastes of human vital activity and for regeneration of ion-exchange resins and other sorbents.

The main nitrogen-bearing product of urine is urea. It contains about 80% of the total urine nitrogen [1]. In regard to its chemical structure, urea can be considered as an amide of carbamic acid or a complete amide of carbonic acid; consequently, all urea nitrogen is in amide form [2]. Therefore, all the nitrogen, as a rule, is given off in the form of ammonia in decomposition.

The fastest and most convenient method for urea decomposition without great expenditures of energy is the enzyme method. The decomposition of urea is accomplished by means of the urease enzyme. Urea decomposition products are ammonia in the form of ammonium sal and carbonic acid. The process of urea decomposition with urease proceeds best at 37-38°; however, decomposition does occur at lower temperatures [2, 3]. According to Hendel's data [4], the treatment of urea with urease requires from 0.5 to 10 hours, depending on the amount of the enzyme used. According to his calculations, 300 g of this enzyme is required for a closed system with a crew of six persons for six weeks. The power required for this process amounts to a total of several watts per person.

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There are other methods for urea decomposition in addition to the enzyme method [5]. The method of thermal decomposition of urea can be the most acceptable. The decomposition of urea begins at a temperature of 100°, but the decomposition process proceeds more rapidly at higher temperatures. It must be noted that if urea is heated to a temperature above the melting point, biuret is formed; negligibly small amounts of this substance have a destructive effect on plants.
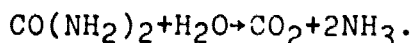
The ammonia produced after decomposition of urea can be used for producing both ammonia water and nitric acid.

This work presents physical and chemical methods for pro- /158
ducing ammonia water and nitric acid from urine urea.

Urea decomposition with urease. For this process, 2 g crystalline urease and 300 mℓ phosphate buffer were added to 1ℓ fresh urine. The mixture was agitated well and placed in a temperature-controlled chamber with a temperature of +37°.

The phosphate buffer was not added in another series of experiments. Samples were taken from the test mixture just before the beginning of the experiment and every 20 min. for 3 hours, and the amounts of ammonia and urea were determined by the Convey method. The results of this series of experiments are presented in fig. 1. One can see that a process of rapid decomposition of urea occurred under the action of the urease enzyme, both in the presence of the buffer (curve 1) and without it (curve 2); the process can be represented as follows:
$$CO(NH_2)_2 + H_2O \rightarrow CO_2 + 2NH_3.$$
Curves of the loss of urea nitrogen were almost a mirror image of curves of the increase in ammonia nitrogen. These processes proceed especially rapidly in the first 20 min. from the beginning of the experiment (19-39% of the urea breaks down during this

period), after which the rate of these processes declines significantly. Under the conditions of the experiment, the urea contained in 1 ℓ of urine is practically completely decomposed in three hours.
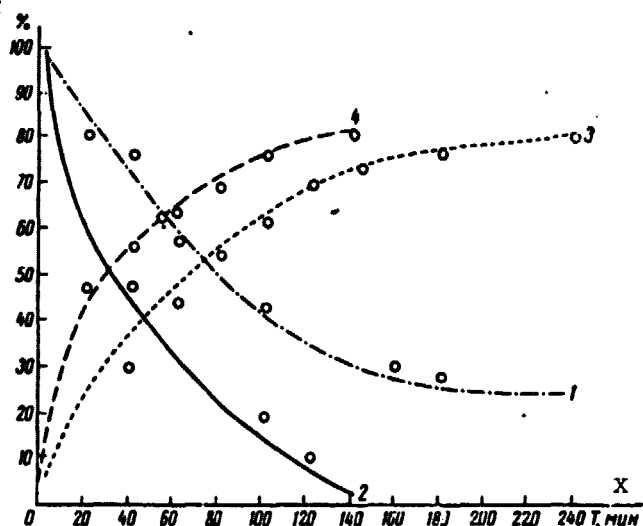
Fig. 1. Decomposition of urea with urease in the presence (1) and absence (2) of a buffer and accumulation of ammonia in the presence (3) and absence (4) of the buffer. Key: x - time, in minutes

Urea decomposition by heating. The urine was heated to a boil, and 90-95% of the water was eliminated. Then heating of the concentrated urine together with the sediment was continued carefully for 24 hours with a reverse cooler. The temperature in the flask did not exceed 115°. The decomposition of the urea was judged according to the increase in the quantity of ammonia.

The urea decomposition process under heating can be represented in the form of the following equations:

$$CO(NH_2)_2 + 2H_2O = CO(ONH_4)_2,$$
$$(NH_4)_2CO_3 = 2NH_3 + CO_2 + H_2O.$$
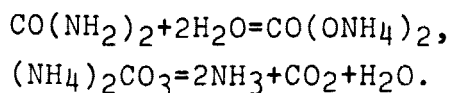
The urea decomposition process began during elimination of the water. From 31 to 41% of the ammonia was eliminated along with the water. Under heating of the concentrated urine, the accumulation of ammonia occurred gradually. The quantity of ammonia increased by 3-4% every hour, and from 76 to 93% of the

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urea was decomposed in 24 hours. A reaction for biuret was negative in the mixture remaining after removal of the ammonia.

Production of ammonia water. Ammonia water was produced from urine subjected to enzyme or physical and chemical processing in the device schematically represented in fig. 2.

Urine treated with urease was placed in an evaporator (2). In heating of the mixture from 70 to 100°, ammonium hydroxide and ammonium salts were broken down, and ammonia was given off. The ammonia, together with water vapor, air and part of the organic matter, passed into a catalytic furnace (3) filled with hopcalite, where oxidation of the substances occurred over the catalyst at a temperatureof 150°. The temperature was regulated by means of an automatic self-recording potentiometer (4). No ammonia oxidation was observed, since higher temperatures are required for this process.
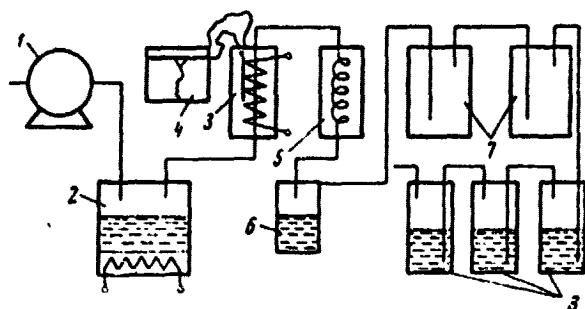
The organic matter was oxidized over the catalyst with air oxygen, which was fed into the furnace at definite rate. From the furnace, the ammonia with the water vapor passed into a cooler (5), in which the water vapor was condensed, and the ammonia was partially dissolved.

Fig. 2. A diagram of the installation for producing ammonia water and nitric acid

The water and the ammonia dissolved in it entered a receptacle (6). However, not all the ammonia could be dissolved in the condensate produced, and part of it passed on into traps (8), where it was absorbed by water. The ammonia residue was trap-

ped with sulfuric acid. This method made it possible to produce ammonia water with an oxidizability in regard to permanganate of 24 mg O_2/l and an ammonia yield of up to 94% of the ammonia in the source. The dependence of the ammonia yield on the rate of air flow through the furnace at a constant amount of hopcalite was investigated in these experiments. At an air flow rate of 3.5 l per minute, fuller oxidation of the organic matter occurred, and the ammonia water produced had an oxidizability of 0.7 mg O_2/l. However, part of the ammonia was apparently oxidized to elementary nitrogen, since the ammonia yield amounted to only 61 to 68%.

At an air flow rate of 5 l/min., where the time of contact with the catalyst was shorter, the ammonia yield increased to 91-94%, although the oxidizability of the ammonia water increased somewhat (24 mg O_2/l).

Production of nitric acid. Nitric acid was produced in the same installation (see fig. 2). Hopcalite and metallic platinum in the form of wire with a diameter of 0.09 mm were used as catalysts. Since a higher temperature is required for ammonia oxidation, the experiments were conducted at 500-600°C. The oxides of nitrogen produced passed into the cooler together with water vapor and air, and the water vapor was condensed. The water with oxides entered a receptacle, where the nitrogen dioxide formed was partially dissolved in the condensate. Then the nitrogen oxides passed oxidizer receptacles (7), where the nitric oxide was gradually subjected to further oxidation to nitrogen dioxide. The entire process can be described by the following equations:

$$4NH_3+5O_2=4NO+6H_2O,$$
$$2NO+O_2=2NO_2.$$
$$2NO_2+H_2O=HNO_3+HNO_2,$$
$$3HNO_2=HNO_3+2NO+H_2O.$$
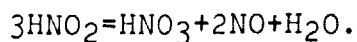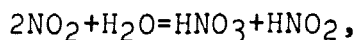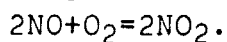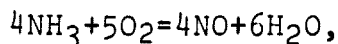
The oxidation of ammonia was accomplished with air oxygen, which

passed through the system at a rate of 4-5 ℓ per minute. According to the reaction, 1.25 moles oxygen is required for 1 mole ammonia.

It is known that the amount of oxidizable ammonia depends on the ratio $O_2:NH_3$ and the ammonia concentration in the mixture of ammonia and air. According to published data [6,7], with the use of a platinum catalyst at a temperature of 600°, the ratio $O_2:NH_3$ should be no greater than 1.7 at an ammonia concentration in the mixture of ammonia and air of 9.5-11.5%. The overall reaction, which determines the need for oxygen, is expressed by the following equation:

$$NH_3+2O_2=HNO_3+H_2O.$$
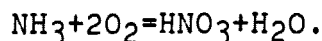
According to this reaction, the ratio $O_2:NH_3$ is 2, and the ammonia concentration in the air mixture should be no greater than 9.5%.

Since nitric acid was produced directly from urine in the actual experiments, the quantity of ammonia passing over the catalysts could not be evenly dosed. The quantity in the mixture of ammonia and air fluctuated from 5 to 16.7% in the first 20 minutes at a ratio $O_2:NH_3$ of 1.56-3.9. Under these conditions, the amount of oxygen was sufficient for ammonia oxidation. The quantity of ammonia in the air mixture subsequently dropped sharply. At the same time, the air flow rate remained constant; therefore, a significant oxygen surplus was observed. The kinetics of the loss of ammonia from the solution (curve 1) and the increase in oxides of nitrogen (curve 2) are shown in fig. 3.

No additional oxygen was added for the second stage of nitric acid production, i.e., the oxidation of NO to NO_2; as a result, nitrogen was obtained primarily in nitrite form as nitrous acid salts (97%). In this process, nitrous acid salts with a total yield in regard to nitrogen of 51-52% were produced over a hop-

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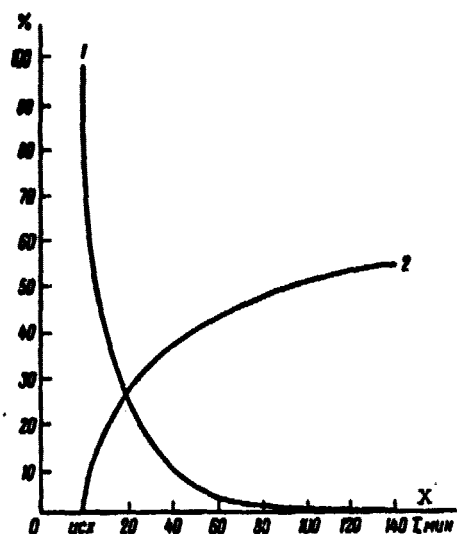Fig. 3. The kinetics of ammonia oxidation. 1 - the loss of ammonia from the solution; 2 - the increase in oxidized nitrogen. Key: x - time, in minutes

calite catalyst at a temperature of 300-500°. The yield was 61% with the use of a platinum catalyst at a temperature of about 600°C.

Consequently, preliminary research has demonstrated the possibility of producing ammonia water and nitric acid from urine by catalytic oxidation.

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THE PROBLEM OF EXTRACTING SODIUM CHLORIDE FROM MINERALIZED PRODUCTS OF HUMAN VITAL ACTIVITY IN A CLOSED SYSTEM FOR RECYCLING SUBSTANCES

V. S. Soldatov, L. I. Tsukurova and I. V. Girey

For creating a normal habitat for human beings and for fauna and flora in a closed system for recycling of substances, the extraction of sodium chloride from products of human vital activity and the activity of the biological complex is necessary.

This problem is complicated in practice by several circumstances. Some of them, such as the similarity of the chemical and physicochemical properties of the components present in the mineralized mixture, especially Na^+, K^+, NH_4^+, Cl^- and NO_3^-, have a fundamental character. Others are conditioned by practical difficulties or inconveniences which emerge in attempts to separate such mixtures (the great duration or complexity of the process, high energy expenditures, etc.).

The authors have tested several methods for extracting sodium chloride from a mixture containing Na^+, K^+, NH^+, Mg^{++}, Ca^{++}, Fe^{+++}, Cl^-, NO_3^-, SO_4^{--}, PO_4^{---} and CO_3^{--} ions. This report is devoted to a description of some of them.

In one of the variants of the experiment, the mixture was preliminarily treated so as to produce all metal cations in the form of chloride salts and all anions in the form of ammonium salts. For this purpose, the mixture in question was preliminarily dissolved and separated from the precipitate (phosphates of magnesium, calcium and iron). In this process, if the quantity of Mg^{++} and Ca^{++} in the mixture being separated exceeds the concentration of PO, these ions partially remain in solution, while the PO ion is practically absent. In the opposite case, the surplus amount of PO remains in solution along with negligibly

small quantities of Mg^{++} and Ca^{++}. Iron, whose concentration is low, passes into insoluble phosphate in any case.

Sodium extraction from a cation mixture. The most complex variant for sodium extraction, when Mg^{++} and Ca^{++} are present in a cation mixture, is examined. The solution is passed through a column (with KU-2 ionite in NH_4^+ form), whose total capacity is at least twice as great as the cation concentration in solution. The cations sorbed by the ionite are displaced with 1 N NH_4Cl, and the flushing water contains a mixture of all cations in the form of chloride salts and a surplus of NH_4Cl. The solution is evaporated, and the dry residue is heated at 350°C until the NH_4Cl is completely eliminated. The salt mixture of NaCl, KCl, $MgCl_2$ and $CaCl_2$ is treated with ethyl alcohol. The $MgCl_2$ and $CaCl_2$ pass into solution, while the NaCl and KCl are washed again with a 96% solution of alcohol in water (100 ml of alcohol for 50 g of salts). The NaCl and KCl remain almost completely in the residue in the form of finely dispersed powder.

The minimum volume of water necessary for dissolving at 100° is poured over the mixture of NaCl and KCl, after which the solution is concentrated by evaporation and cooled, so that the crystals formed are easily wetted by the mother-liquor. Then the mixture of crystals is placed in a flotation machine of the normal design with a capacity of 50 ml (15 g salt for 40 ml of the mother-liquor). A saturated solution of NaCl and KCl is used for the circulating mother-liquor. A 0.5% solution of octadecylamine in a quantity of 0.2 ml for 15 g of salt is added to the mother-liquor.

The mixture is frother quickly with a rotating mixer. In this process, the KCl passes out with the foam, while the NaCl remains unfiltered. Next the separated salts are pressed and dried. The duration of the flotation process does not exceed 7

minutes, and the energy consumption is slight. Sodium chloride separated in this manner contains a 20% KCl admixture, and the KCl contains approximately the same amount of NaCl, if NaCl and KCl were present in the initial mixture in equal amounts. There is no doubt that the efficiency of flotation separation can be increased by developing the optimum conditions for flotation and precipitation of the crystals.

Chlorides of sodium and potassium can also be extracted by flotation from a mixture which has not been preliminarily treated with alcohol; however, magnesium and calcium, which are present in considerable amounts, interfere with the flotation process and should be removed in advance. The authors obtained good results in eliminating Mg^{++} and Ca^{++} by means of KB-4 ionite, which was used for preliminary treatment of the mixture. Fig. 1 shows that the separation of Mg^{++} and Ca^{++} from Na^+ and K^+ is easily achieved. There is no need in this case for strong solutions of extraction agents, which is quite necessary in working with KU-2 ionite.

The method of chromatographic extraction of Na^+ from the mixture of all the cations with KU-2 ionite was also tested. It was possible to solve the problem by this method; however, when /165 the duration of the process, the high energy consumption and the relatively low reliability are taken into consideration, it is less suitable for preparative extraction of NaCl.

Extraction of Cl^- from an anion mixture. Difficulties of the same character as in the extraction of Na^+ with cationites arise in the extraction of Cl^- from an anion mixture by the chromatographic method with the use of anionites. Moreover, anionites are less stable in use than cationites, can sharply change their properties under the influence of the temperature and of chemical effects, and in contact with water give off
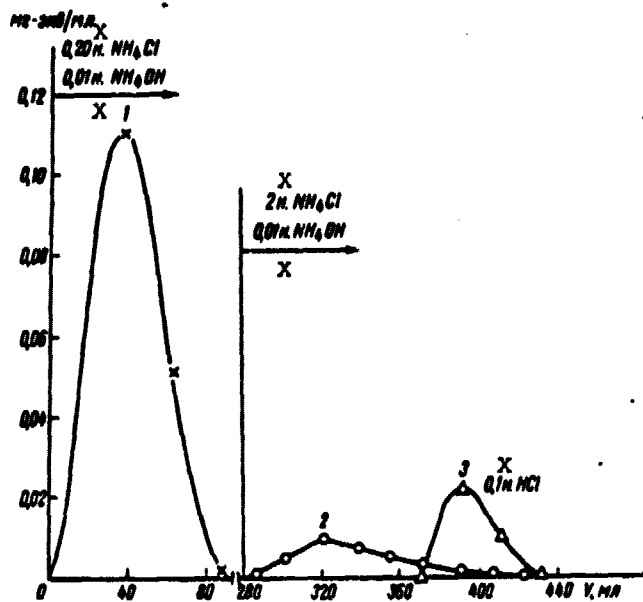
Fig. 1. Flushing of cations (in mg equiv./ml) from a column of KF-4 ionite in NH_4^+ form. 1 - Na^+, K^+; 2 and 3 - Mg^{++}, Ca^{++}; V - extraction agent volume, in ml. Degree of loading, 20%. Column length, 17 cm; diameter, 1 cm. Weight of ionite in H^+ form, 5 g. Exchange capacity, 10.22 mg equiv./g. Na^++K^+ injected, 9.52 mg equiv.; flushed out, 9.34 mg equiv. $Mg^{++}+Ca^{++}$ injected, 1.30 mg equiv.; flushed out, 1.08 mg equiv. Key: x - N

toxic substances. Therefore, the chromatographic method was rejected for separation of Cl^- from the other anions. The authors consider fractional sublimation of ammonium salts the most promising of the other tested methods. The kinetics of sublimation of all individual ammonium salts was studied preliminarily at various temperatures, and it was established that temperature conditions suitable for extraction of ammonium chloride are easily selected.

Fig. 2 shows that with an increase in temperature to 290°C and heating for 30 minutes, NH_4Cl escapes, and $(NH_4)_2SO_4$ remains completely. Ammonium phosphate also fails to undergo sublimation. The NH_4NO_3 and $(NH_4)_2CO_3$ which are present in small amounts do not hinder separation, since the latter is eliminated at 140°, while the ammonium nitrate decomposes in the range of 250-290°C with the formation of gaseous products.
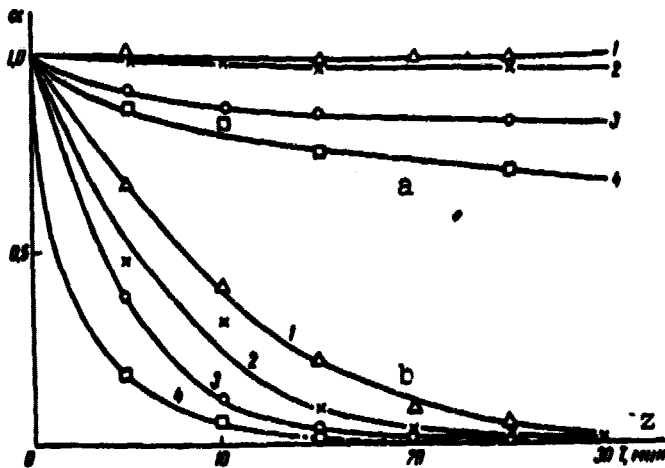
Fig. 2. The dependence of the proportion (α) of $(NH_4)_2SO_4$ (a) and NH_4Cl (b) which are not sublimated on the time of heating at a ratio of $SO_4^{--}:Cl^-$ in the initial mixture of 1:2. 1 - 290°; 2 - 303°; 3 - 322°; 4 - 340. Key: z - time, in minutes

Conclusions

1. Several methods for extraction of sodium chloride from mineral media identical in composition to mineralized biological media have been investigated.

2. The flotation method is suggested for preparative extraction of Na^+ from the cation mixture, and the method of fractional sublimation is recommended for extraction of Cl^- from the anion mixture.

MOISTURE-CONTAINING HUMAN WASTES AS A PRODUCT FOR OBTAINING THE MAIN ELEMENTS FOR AUTOTROPH NUTRITION

G. I. Kozyrevskaya, Yu. S. Koloskova, N. N. Sitnikova
and V. I. Yazdovskiy

Human feces and urine are one of the main sources of nitro- /166
gen, phosphorus, potassium and a number of other elements which
can be used by higher and lower plants in a closed system after
mineralization.

According to domestic and foreign published data, the quali-
tative compositions of feces and urine have been investigated
with sufficient thoroughness [1-5]. However, the quantitative
ratios of the main components of urine and feces have been stu-
died only from the point of view of the requirements of clinical
medicine; data on the elementary compositions of these products
are almost totally lacking in the literature. Published data on
individual deviations in the compositions of feces and urine are
also inadequate.

These questions take on definite importance in the develop-
ment of methods for mineralizing the wastes of human vital acti-
vity in a closed ecological environment, where knowledge of the
slightest fluctuations in the concentrations of substances in
the system is absolutely necessary for maintaining a strict ba-
lance.

The research of physiologists and biochemists indicates
that qualitative and quantitative variations in urine and feces
depend on many factors, including a person's state of mind, mo-
tor and water conditions, the food ration, the functional condi-
tion of the intestines, the temperature and humidity of the en-
vironment and the barometric pressure.

The study of the effects of these factors on the qualitative

and quantitative variations in urine and feces takes on particular importance when the person is in a limited, closed space, such as the cabin of a spacecraft.

This work is the first attempt to analyze certain experimental data on the qualitative and quantitative fluctuations in the compositions of feces and urine from different donors.

The indices presented in this work were not selected at random. They conform to the principles of the scheme for biological mineralization of feces and urine developed in our laboratory. The indices of interest to us include:

1) the weight of the daily portion of feces, its moisture content, the amounts of soluble and insoluble components, the total quantity of organic substances in the feces and in each fraction (soluble and insoluble) individually, the amounts of total nitrogen, ammonium nitrogen, nitrite and nitrate nitrogen, and the compositions of mineral salts;

2) the size of the daily portion of urine, the concentration of organic substances in it in different daily portions, and fluctuations in the quantity of urea.

Feces and urine for the investigations indicated above were collected in October-December. The donors included both persons selected at random and specially selected, clinically healthy researchers. The nutritional conditions were extremely varied and arbitrary.

The excrement was weighed, and weights of 2-3 g were taken for determining the moisture content. The remaining mass was brought to a volume of 100 ml with tap water and homogenized for 30-60 minutes, after which the soluble portion was separated from

the insoluble portion with a centrifuge. The insoluble portion
of the feces was dried after centrifuging for determining the
dry weight. Only the soluble portion passed on for biological
mineralization.

Urine was collected in individual portions during the day;
in addition, urine was collected for several days from a number
of researchers for obtaining average daily quantitative data
and data on the qualitative and quantitative variations in chemi-
cal compositions of different daily portions.

The total quantity of organic substances in the excrement
and urine was determined by the bichromate method and expressed
in milligrams of O_2. The other indices were determined according
to procedures adopted at our laboratory.

The weight characteristics of the daily portions of excre-
ment of various donors and the total quantity of organic substan-
ces in the soluble and insoluble fractions were as follows:

a Сырой вес. г	b Влаж- ность. %	c Сухой вес. г			g Количество органического вещества, мгО₂·10³	
		d всей пор- ции	e раствори- мой части	f нераство- римой части	h во всей пор- ции	i в растворимой части
215±69	83±2	43±14	26±8	17±5	79±29	14±3.2

Key: a - raw weight, in g; b - moisture content, in %;
c - dry weight, in g; d - entire portion; e - soluble portion;
f - insoluble portion; g - quantity of organic matter, in mg
$O_2 \cdot 10^3$; h - in the entire portion; i - in the soluble portion.

It is apparent that the daily portion weight characteristics
from different donors have great individual fluctuations.

The main mass of organic substances is found in the insoluble
portion of the feces. The soluble portion contains only 18% of
all organic substances in the feces.

The Forms of Nitrogen Included in the Composition of Feces

According to published data, protein metabolism products released from the intestine leave it in the form of organic nitrogen. Only a small portion is represented by mineral substances in the form of ammonia nitrogen (0.02-0.2%) and nitrate nitrogen (traces).

Analyses have demonstrated that the total nitrogen of the daily portion of excrement (whose average dry weight is 50 g) fluctuates from 1050 to 1950 mg, with from 2.5 to 500 mg for ammonium nitrogen (0.17 to 35% of the total nitrogen) and from 0 to 160 mg for nitrate nitrogen (0-11.0% of the total nitrogen).

These data attest to the fact that while the total nitrogen is released from the organism in the composition of the excrement with a certain degree of constancy, the amounts of mineral forms of nitrogen in the excrement fluctuate sharply. Individual portions of feces contained up to 35% ammonium and up to 11% nitrate nitrogen, which corresponds to the final stages of mineralization of nitrogen-containing organic substances. Cases in which the daily excrement portion contained a great deal of ammonia and nitrate nitrogen involved subjects with atonic intestines.

Prolonged congestion of the feces leads to mineralization processes under the influence of the intestinal microflora. This is confirmed by the fact that the nitrate nitrogen in the daily excrement portion is in inverse proportion to the total quantity of organic substances, determined according to the chemical consumption of oxygen.

In the biological mineralization systems under construction, excrement is the main source of mineral substances. According to

published data, feces contain up to 8% phosphates of calcium and magnesium. From the data of the physiology and biochemistry of digestion, we know that the qualitative composition of the food influences the ways of removal of phosphorus and calcium salts. With food rich in proteins, the main mass of phosphorus and calcium compounds is passed with the urine in the form of easily soluble alkali metal salts (such as NaH_2PO_4). With food rich in fat, insoluble salts of calcium and magnesium phosphates are passed with the fecal matter. Therefore, the distributions of these salts between soluble and insoluble portions of the fecal matter can be studied only with a definite food ration. Since no such possibility was available to us, the investigation was performed on a mixture of the daily portions of feces and urine.

The experiments demonstrated that mineral phosphorus makes up almost half of all phosphorus compounds, on the average. The organic phosphorus is made up of 40% soluble compounds and 60% substances included in the compositions of solid, insoluble portions of the feces. With respect to calcium and magnesium salts, they are represented primarily by mineral compounds which are extremely sensitive to variations in the pH of the medium and can undergo up to 80% precipitation in alkalization of the medium, which occurs in hydrolysis of urea and the formation of ammonia.

Since the urine is a source of nitrogen, the authors con- ducted investigations to discover fluctuations in the urea concentration and the total quantity of organic substances in the daily portions (see table).

The data presented in the table indicate considerable fluctuations in the concentrations of both the total organic matter and the urea in different daily portions of urine.

CHARACTERISTICS OF DIFFERENT DAILY PORTIONS OF URINE

a Дата	Общее количество органического вещества. o мгO₂/л	Количество мочевины, p г/л	a Дата	Общее количество органического вещества. o мгO₂/л	Количество мочевины. p г/л
b 14/IX	14700	—	i 29/X	25200	17
c 18/IX	36000	18	j 30/X	23000	—
d 21/IX	25600	16	k 1/XI	34400	—
e 23/IX	13600	14	l 2/XI	24000	7
f 25/IX	22000	15,2	m 3/XI	30000	—
g 26/X	24000	—	n 15/XI	24800	—
h 28/X	18400	12			

Key: a – date; b – September 14; c – September 18; d – September 21; e – September 23; f – September 25; g – October 26; h – October 28; i – October 29; j – October 30; k – November 1; l – November 2; m – November 3; n – November 15; o – total quantity of organic matter, in mg O_2/ℓ; p – quantity of urea, in g/ℓ

In the next stage of the research, experiments were performed to determine the possible daily fluctuations in organic substances in the urine. Experimental data obtained in examining a number of researchers indicate that morning urine portions contain the greatest quantities of urea. The concentration drops in the middle of the day and again increase somewhat by evening. Consequently, a very accurate representation of the qualitative and quantitative compositions of the urine can be obtained only with analysis of the daily portion.

The urea concentration in the urine is a direct indication of the intensity of protein metabolism occurring in the body and naturally depends on the quantity of protein injested with the food. This is confirmed by the fact that the quantity of urea fluctuates during the day:

Hours of the day: 7;   12;   20;   23;   7;
Amount of
     urea, in g/ℓ: 16±3; 15±4; 16±0; 15±1.5; 19±5.

The composition of microflora in the initial urine-fecal
mixture is determined by the microflora of the feces, since the
freshly extracted urine added is sterile according to standard.
The microflora of the feces, its quantity and its quantitative
composition are subject to enormous fluctuations, both indivi-
dual and daily, depending on the food composition and the con-
dition of the intestine. Quantitative fluctuations are also
possible in the compositions of certain physiological groups of
microorganisms:

a Общее количество микроорганизмов, в тысячах на 1 мл (рост на МПА)	b Количество клеток, в тысячах на 1 мл моче-каловой смеси:			f E. coli
	c аммонифика-торы	d нитрифика-торы	e денитри-фикаторы	
21 000 ± 10 000	440 ± 200	0.85 ± 0.6	43 ± 38	507 ± 370

Key: a - total quantity of microorganisms, in thousands per ml
(growth on beef-extract agar); b - quantity of cells, in thousands
per ml of urine-fecal mixture; c - ammonification organisms; d -
nitrification organisms; e - denitrification organisms; f - E.
coli.

Ammonification organisms make up the main mass of intestinal
microflora. The presence of a large quantity of ammonification
organisms indicates that processes of mineralization of nitrogen-
containing organic substances (amino acids) have already begun
in the human intestine, which is confirmed by our data, indicating
the presence of ammonia in the initial product. The possible
ranges of fluctuations in the quantities of microorganisms in all
groups amount to from 45 to 86%.

Conclusions

1. The daily weight of the feces of the researchers fluc-
tuates from 150 to 300 g.

2. The quantity of organic substances in the feces according
to the chemical consumption of oxygen fluctuates from 50,000 to

108,000 mg O_2/ℓ.

3. The food composition and the functional condition of the intestine influence the amount of ammonia given off.

4. The quantities of organic substances (according to the chemical consumption of oxygen) in different daily portions of the urine fluctuate from 13,000 to 36,000 mg O_2/ℓ. The amounts of urea vary from 7 to 18 g/ℓ.

5. The quantity of microorganisms of different physiological groups extracted from the urine-fecal mixture fluctuates in the range from 45 to 86%.

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