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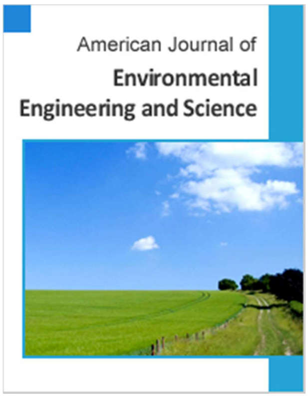

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Historical Review on Problem Solution for Breeding Fish and Quails Under Space Conditions

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Abstract
This article presents the results of scientific and technical work to create space instruments held in the USSR. For the first time data about devices “Aquarium” and “Incubator” created at the Department of Applied Mechanics, Dnepropetrovsk State University, are provided. The names of the scientists who worked on the development of the units are introduced to the world. This became possible only after publishing the materials of those engineering reports which has been kept as classified information of “top secret”.

1. Introduction

The 20th century progress demanded from rocket engineering and space science finding the methods and means in order to provide life activity for people under space conditions. For this, they needed to develop the ecological system of the Earth type, which would ensure residence of human beings in closed rooms of space stations or spacecrafts during lengthy flights held out of the biosphere environment.

By starting elaboration of the principles for ecological system construction in-space, the scientists considered their ideal prototype of a “spacecraft” created by the nature itself – our Planet. The Earth possesses the closed cycle of vital matters: constant consumption and regeneration of water and nitrogen, cyclical conversion of oxygen into carbon dioxide with animals breathing and carbon dioxide into oxygen with photosynthesis of vegetation.

It was generally agreed that the true step of Man out of the Planet would be real only when self-replicating mechanism, which is able to produce the environment for people and ensure the continuousness of life on the Earth, were taken together with people into the space. The science has known the only mechanism of such a kind – natural biosphere of the Earth in whole. It is the very issue to allow the opportunities for infinitely long existence of those species, which have managed to enter into the Earth’s cycle of matters [1].

Among the works of Ukrainian historians of science can be distinguished work on the history of rocketry. As a famous and important historical labors, should determine dissertation O. A. Kopyl, I. A. Pistolenko, I. V. Fedorenko [2, 3, 4]. But these works are not mentioned about space devices such as “Aquarium” and “Incubator”.

2. Main Body

Considering all the aspects of the lengthy existence of living objects out of the Earth biosphere, paper [5] comes to the conclusion that all the ecological systems in the history of their development can be classified into biologically closed and biologically opened ones.

Before the turn of the space era, the scientists from various countries had been widely studying behaviour and states of living organisms under flight conditions on board of special airplanes and geophysical rockets for decades [5]. The activities concentrated on the problems how various animals and a human being would tolerate the states of weightlessness, g-load, solar radiation, or cosmic rays.

The first life support systems of closed type were used by the investigators at the end 40s and beginning of 50s, the period of time when high-altitude balloons and rocketsondes with small vertebrate animals and other biological objects on board were launched into the stratosphere [6]. Those life support systems actually were equipped only with the source of compressed air and contained neither food nor water supplies (or food was in limited amounts). Regeneration systems for life activity products collection and storage did not exist at all.

Medical and biological investigations in the USSR started in 1951 with high-altitude geophysical rockets. The second 1957 satellite allowed deeper studies on weightlessness effect on the organism of a dog Laika. Since 1962 the regular launchings of “Kosmos” sputniks have been made. The sputniks of “Kosmos-92, 94, 109” carried the seeds of garden radishes, kidney beans, tomatoes, cabbages, lettuces, carrots and unicellular weeds of chlorella, all this was placed in special containers.

Lengthy flight of “Saliut” station in 1971 provided the opportunities for conducting experiments on monitoring the processes of organisms maturation and their functions development; the experiments were made on spawns of amphibias, seeds of higher plants and insects with the use of “Oazis” [6].

The systems for the first orbital animal flights (the flights with dogs called Laika, Belka, Strelka and Zvezdochka in the former USSR projects and chimpanzee Enos in the US project) were constructed and became a step forward to creation of more sophisticated life support systems. They were mainly developed with the objective to sustain lives of animals until important physiological data are collected and transmitted to the Earth [6]. With the time passed, there was no need for improvements on the life support systems of unclosed type for animals.

A closed ecological system for human life support with autonomous control was modeled in BIOS-3 experimental complex, created by Institute of Biophysicists, Krasnoyarsk, Russia [6]. In BIOS -3, they carried out 10 experiments with the crews consisting of from 3 to 5 people. The longest of the experiments lasted 180 days in the period of 1972—1973. The scientists managed to achieve the full closing of the system in terms of gaseous and water media and food self-provision in amounts up to 80% of the crew needs. The terrestrial experiments could not be fully authentic because of a very significant factor to be present in space – weightlessness [6].

Passing over to the experiments under weightlessness permitted solving one important problem of biology – evaluation how space factors influence an organism development. The special place was given to embryogenesis study. Investigation of the embryonal development under space flight conditions enabled the usage of the embryological object as a sensitive indicator with the purpose to study how physical factors accompanying a space flight influence a living organism. These factors are g-loads, vibrations, weightlessness, and radiation. An embryo, especially on the earliest stages of its development, is much more sensitive to the various factors than the born living organisms. The most suitable for experiments under conditions of rocket launching and space flight were Japanese quails [7], the fact that this species of quails has the ability of fast reproduction (a hen gives 300 eggs a year) also contributed to the scientists’ choice.

For feeding the quails, unicellular seaweeds and the rests of human nutrition were used. These quails are resistant to ionizing radiation, their data are quite stable and along with it these birds have a certain reaction to stressing issues. The information on genetics, selection, physiology, embryology, endocrinology and histology for this species has been well known [7]. By 1982 the experiments to know how accelerated additional loads and hypokinesia affect protein metabolism in the organisms of Japanese quails had been performed. The influence of the above mentioned factors on the human’s organism also took place. Ovogenesis rate of Japanese quails is a sensitive indicator for the changes in the environment. The problems of weightlessness affect embryogenesis of birds and the opportunity to use the artificial gravity as a means for prevention of weightlessness adverse effects attracted scientific interest.

Since 1977 Russian scientist V. Yakimov has been constructing new types of “Incubator” units [8]. He proposed the methodology for the terrestrial experiments with “Incubator”. The results have revealed that laying hens aging from 7 to 9 months old, which had been receiving 0.32 volume percent sodium bicarbonate, had lower rates of elastic deformation and consequently less number of eggs with shell defects compared against the results of the control set of hens.

Starting from the year of 1979 the scientific group of engineers and biologists had been formed with professor I. K. Kosko in charge within the Department of Applied Mechanics of Dnipropetrovsk National University (DNU), Ukraine. For the developments in the sphere of Biomechanics, there were concluded agreements on elaboration of themes No. 792, No. 250-76, No. 894, No. 846, which resulted in 17 certificates of authorship and 32 engineering reports.

With a number of experiments, the workers of the DNU Department of Applied Mechanics, namely N. A. Zayats and L. N. Vasilenko, under the guidance of a principle investigator I. K. Kosko developed an experimental unit of "Incubator". This unit belongs to the types to be applied for biological objects incubation, for example bird eggs, and also for biological investigations under space flight conditions [9].

There were several modifications on the developed "Incubators". The first unit aimed at studies how the certain rates of rotational angular motion influence the development of biological objects when the rate of artificial gravity created in weightlessness of a space flight is the same [10].

Fig. 1 and 2 show the photos of laboratory unit "Incubator", fig. 3 is "Incubator" unit cell photo.

Fig. 1. *General view of unit "Incubator".*

Fig. 2. *Laboratory unit "Incubator".*

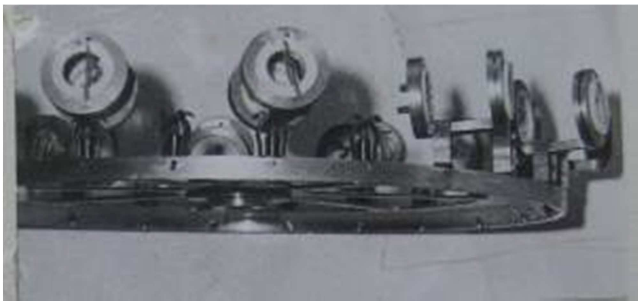

Fig. 3. *A discrete cell of unit "Incubator".*

The tests have shown high reliability of "Incubator" unit. The range of the sustained temperature accuracy is within 0.01°C while that of relative humidity is 5% [11].

In order to study how the conditions of gravity absence and other space factors influence the development of an embryo, scientists N. A. Zayats and A. I. Varakuta started the work on "Aquarium" unit development [12] in 1980 within the framework of theme No. 894. The experiment at this unit could last long enough without human interference. The unit incorporated two chain systems made up of higher water plants and fishes. From a biological standpoint, "Aquarium" is a closed ecological system with organized element circulation. One of the fish species to be grown under weightlessness conditions was a big size kind of tilapia fish, which eats water plants. Seaweed chlorella was used as the food for the fish. It also was the principle oxygen producer.

The unit of "Aquarium" consists of a transparent body, evacuation system, nets, luminous tube lamp and the section with seaweed [13]. Conducting the experiments, N. A. Zayats and A. I. Varakuta under scientific supervision of professor I. K. Kosko developed methodology to prepare "Aquarium" for testing period and experimental performance.

In 1982, the workers of DNU Department of Applied Mechanics, I. K. Kosko, N. A. Zayats, and L. N. Vasilenko, made changes in the construction of "Aquarium" (fig. 4), which enabled improvements on the design to make it more suitable and reliable for operation. The rod handles were enlarged and the body construction was strengthened in order to provide better characteristics of lamp suspension. The back end cover of the body was made stronger [14].

The works devoted to unit "Aquarium" development were carried out as fulfillment of preliminary specifications issued by Space Research Institute of Russian Academy of Sciences (IKI). "Aquarium" participated in biological experiments during the flight of biosputnik No. 9 of "Kosmos" series.

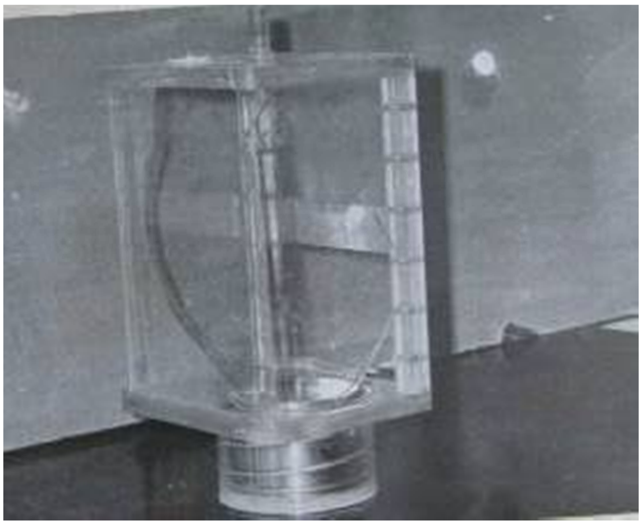

Fig. 4. *Unit "Aquarium" after selective proof tests.*

Scientists of the State Scientific Center of the Russian Federation within the Institute of Biomedical Problems (SSC RF IBMP), namely T. S. Gurjeva, M. A. Levinskikh, O. A.

Dadasheve, A. V. Filatova, V. N. Sychev, investigated how the factors of space flight influence the embryonic growth of Japanese quails. The chicks, which passed their embryogenesis cycle under weightlessness conditions, had all the signs of a normal development. They hatched in a space flight in the same time period as it were on the Earth – the 17^{th} day of incubation. The Japanese quail chicks were active, during the first day they reacted well to the light, sound and food. It is well known that Japanese quails are precocial species which are able to move and to eat on their own right after the birth. The pursuit of the chicks to sustain the genetic reflexes under weightlessness conditions caused their active disordered movements in weightlessness medium. This is related to the interference in usual vertical organization within the gravitational field and absence of load weight bearing on the musculoskeletal system. The investigations of comparative histopathologic findings on 5-days-old chicks showed the drastic differences. The chicks under control had final cellular differentiation of all types of the cells in the spinal cord. The found changes occurred as a reaction of nerve cells to the functional state of the organism, which existed in weightlessness. Decrease in threshold of sensitivity of motor analyzer was observed and resulted in disorders in coordination of movements [15].

In the sequel, the scientists of SSC RF IBMP conjectured that presence of special devices allowing the chicks to be fixed would permit their growth and development in weightlessness. A noticeable amount of works was devoted to studies of possibilities for Japanese quail chick eating behaviour at post-being after the conditions of vertical rotation (clinostating), which started from the second half of embryogenesis and up to the determined time of postnatal developmental period (0 - 1, 4, 6 and 8 hours). The clinostat for the experiments was a vertical wheel of 40 centimeter in diameter (its rotation speed was 2 rotations/minute) with rigidly fixed 16 discrete chambers (50×68×49 mm), where eggs of 12-days-embryonal development were inserted. The clinostat was placed in Bruwa thermostat. In order to identify the start of feeding response the chicks were put from the clinostat discrete chambers into the experimental room. It was revealed that nearly 50% of chicks in every set of the experiments had the initiation of the feeding response during the first 125 seconds. There was discovered a considerable difference in formation of food picking reaction and it was interpreted as inhomogeneousness in the chosen amount of new-born chicks that meant differences in individual peculiarities on new-born chicks. The disorders of the pose and moving activity were notices and they, as the scientists of SSC RF IBMP consider, were related to the decrease in threshold of sensitivity of motor analyzer, which occurred during the period of growth. However, all these changes were reversible. [16].

The chronological historical review on how the idea and principles of ecological systems were developed enables passing over to a direct analysis of how to model the tights between discrete constituents of the ecosphere. The following steps were made with the units and systems, which were used for implementing the ideas of interconnection modeling when discrete constituents became the ecological chain. The first systems carried out this kind of modeling under the Earth conditions. Along with the following development of rocket and space technology, units like "Aquarium", "Hydrostat" and "Incubator" were born to permit creation of a microworld of a separated ecosystem inside a small unit. It should be emphasized that the units were under the same conditions as the planet of the Earth is.

3. Conclusions

1. The chronological historical review on formation and development of a scientific group having worked on building the space units of "Aquarium", "Hydrostat" and "Incubator" is carried out.
2. This paper is the first time when the gaps in historiography of papers, devoted to the development of "Aquarium", "Hydrostat" and "Incubator" units, were filled up and the significance of findings of the Applied Mechanics Department in Dnipropetrovsk National University is reported. The names of the scientists who worked on the development of the units are introduced to the world. This became possible only after publishing the materials of those engineering reports which has been kept as classified information of "top secret".

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