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IDEA OF ECOLOGICAL PURIFICATION SYSTEM FOR DRINKING WATER COMES FROM BROA RESERVOIR

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ABSTRACT

Origin of the refocusing on slow sand filter as an ecological purification system is the observation of un-healthy phytoplankton in Broa reservoir in 1974. Longitudinal profile of phenomena is characteristic feature of a reservoir. Active region is only inflow part. Phytoplankton under hungry condition is normal near the dam site.
Keywords: Slow sand filter; hungry condition; BOD; phytoplankton; drinking water.

RESUMO

A IDÉIA DE UM SISTEMA ECOLÓGICO DE PURIFICAÇÃO PARA ÁGUA POTÁVEL VEM DO RESERVATÓRIO DE BROA. A origem da rediscussão sobre o filtro lento de areia como um sistema ecológico de purificação é a observação do fitoplâncton nocivo no reservatório de Broa em 1974. O perfil longitudinal do fenômeno é uma característica de um reservatório. A região ativa é apenas a parte da entrada. O fitoplâncton sob condições de fome está normalmente na parte da represa.
Palavras-chave: Filtro lento de areia; condição de fome; DBO; fitoplâncton; água potável.

INTRODUCTION

John Gibb in Scotland made artificial clear sub-surface water in a river bed in 1804. He took surface water of the River Clyde. The water was introduced into sedimentation tank and its water was slowly passed a gravel tank and a sand tank in a horizontal direction. James Simpson in London made clear water from the polluted water of the River Thames. The river water was introduced into sedimentation basin and its water was slowly filtered a sand layer in a vertical direction (Figure 1). The filtrate became germ free clear water for drinking water. Present slow sand filtration system was completed in 1829.

The clear water could be simply turned by passing slowly sand layer. They called slow sand filter. At that time, they thought the purification mechanism was mechanical filtration by fine sand. However this image did not express the real principle of the purification process. Slow sand filter is a gentle habitat for biological community. This is a real ecological purification system like as a natural ecosystem. The biological community among the top of the sand layer plays the major activity for purification process. The food chain is the key. This mechanism has been misunderstood in the all over the world by this unsuitable name of slow sand filter. This new idea of ecological purification system came from an observation of Broa reservoir in 1974. I found there were so many un-healthy phytoplanktons under hungry condition in comparison with Japanese lakes.

FRESHWATER RED TIDE ON A RESERVOIR

I found an extra-ordinary heavy bloom of *Peridinium* sp. in the inflow region of a reservoir in Japan in 1972 (Nakamoto 1975). This phenomenon was named as a freshwater red tide on a reservoir. I could not explain the causes of this bloom by the conventional knowledge of lake study which was

mainly focused on the stratified layer and the recycle nutrient from the bottom. There was a great impact of the inflow water on the phenomena in a reservoir. In the case of a lake study which has a long retention time of water. The vertical profile of a water column is important to explain the phenomena. However, a reservoir has a short retention time. There is one way current in a reservoir. Horizontal and longitudinal profile along the water course is more important to explain the phenomena.

BROA STUDY

I visited as an advisor of algal culture technique to the staff of the department of sanitary engineering of USP- São Carlos from August to October in 1974. And I also visited to the group of Prof. Tundisi in UFScar during these 3 months. I visited many times to Broa reservoir when technician went to sampling. There were so many un-healthy phytoplanktons which were almost dead condition or broken algae even in the surface water. I checked the longitudinal difference of phytoplankton and environmental parameters from the inflow region to the dam site.

I made a plan to clarify the longitudinal profile of Broa on the observations of phytoplankton, zooplankton, benthos, bacteria, water quality, and primary production etc. on October 1, 1974. There was a shower on two days before the planed day when it was the end of dry season. However, our plan was performed.

BLOOM AFTER RAIN

We found the periphyton on the littoral zone in the inflow region flushed and drifted into the reservoir (Nakamoto *et al.* 1997). The cell number of the all the colony of filamentous diatom *Melosira italica* was even number. After the rain, nutrient among the soil in the watershed pushed out into the reservoir. The cell division of the phytoplankton under hungry condition began the growth all at once (Nakamoto *et al.* 1976).

ROLE OF FOOD CHAIN

There is a food chain in the ecosystem. Animals catch and eat any things. And they decompose and digest almost all of them. This is our impression of animal's behavior. However, animal can assimilate only a part of eaten food which is digested. A major part of eaten food runs just through the enteric canal. Only the small molecule can pass through the wall of the enteric canal and inside the real body. Even some of the living organisms may pass through the enteric canal in the animal body. We checked the excreted phytoplankton in the fecal pellet by fish (Nakamoto & Okino 1972). Diatom was easily assimilated by fish. However, green alga which had strong thick cell wall was not assimilated by fish. One of the important roles of animals is fecal pellet maker in the ecosystem. Facultative anaerobes can grow inside of the fecal pellet. A larger molecule is easily broken to smaller molecule during the fermentation process inside of the fecal pellet where is under anaerobic condition. This small molecule is assimilable for animals.

AFTER A BLOOM, HUNGRY CONDITION

There is constant down ward current in a slow sand filter pond (Figure 1). The biological community is active on the sand surface where is plenty food. Small animals are active among sands at the top of sand layer.

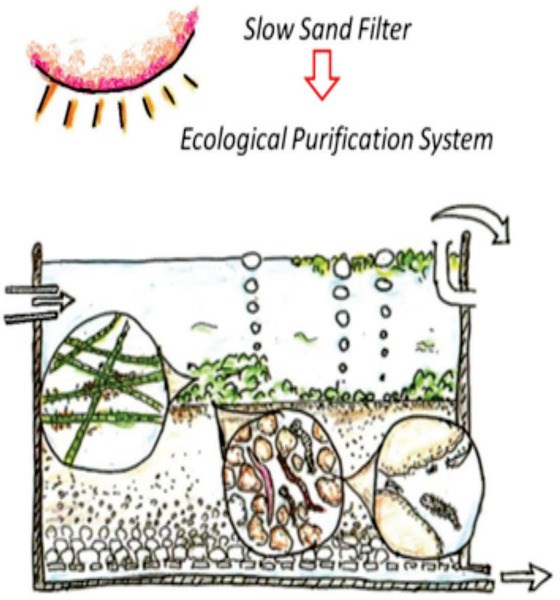

Figure 1. Image of slow sand filter as an ecological purification system: Biological active place is on and beneath the sand surface. Available matters are utilized completely via the food chain by hungry organisms.
Figura 1. *Imagem de um filtro lento de areia como um sistema ecológico de purificação: a atividade biológica sobre e sob a superfície de areia. As matérias disponíveis são completamente utilizadas através da teia alimentar pelos organismos com fome.*

There is a food chain. Almost all the available food is consumed up. There is almost no animals beneath the surface where is scarcely food. There are no animals in further deeper layer. Almost all the animals concentrate on and beneath the surface of the sand layer. Available substances are completely consumed by biological community in the upper part of the sand layer. There is nothing for available matter for organisms in the filtrate passed through the sand layer. Sand is just habitat for organisms and the word of slow means just gentle for organism.

In the case of a reservoir, there is a horizontal current from the inflow region to the dam site. In case of slow sand filter, there is a vertical current from the top of sand layer to the bottom of the sand layer. In both environments, there is a constant current with one direction. Nutrient and food for organisms are brought by the inflow water. Therefore, organisms are active in the inflow region where nutrient and food are brought. Along the water current and along the longitudinal drifting, available matters are consumed up gradually. Any organisms becomes under hungry condition. As the result, the nutrient concentration near the dam site is extremely poor and un-healthy organisms are remarkable.

AVAILABLE NUTRIENT

Idea of the new bioassay technique of MBOD (Modified BOD method) to evaluate available nutrient comes also from Broa reservoir (Nakamoto 1981). There was extremely small amount of nutrient level in the Broa water in comparison with Japanese lakes. This level was hard to evaluate by chemical analysis. It was non-detectable level. However, microorganism can utilize such low level of nutrient in natural environment. The bioassay using the activity of microorganisms is more sensitive than chemical analysis.

At that time, they measured the concentration of dissolved oxygen by Winkler method as routine work. There was enough number of oxygen bottles. In order to evaluate low nutrient level in water, I applied the principle of BOD (Biochemical Oxygen Demand) method to evaluate available organic matter. This idea was based on the law of minimum by Liebig. I put glucose as energy and carbon sources into a glass bottle for the growth of heterotrophic microorganisms. Microbe grew using energy, carbon and nutrients in original water in a bottle. The amount of consumed dissolved oxygen related with the amount of available nutrients in original water (Figure 2). This new assay was named to MBOD (Modified BOD). We could easily evaluate the extremely low level of nutrient in water on the stand point of biological sense. We could evaluate which nutrient of nitrogen or phosphorus was a regulation factor for the growth and we could quantitatively evaluate this level. Broa water was extremely low level of nutrient. All of the nutrients (nitrogen, phosphorus and micronutrients) were really deficient level.

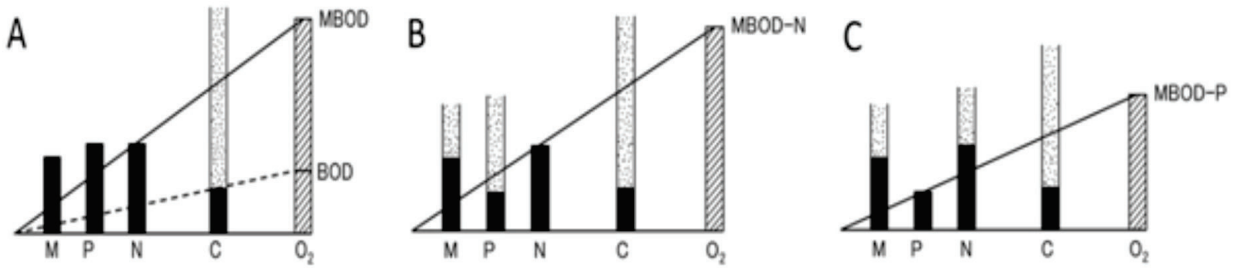

Figure 2. Principle of MBOD method: M expresses micronutrients. P is phosphorus. N is nitrogen. C is carbon source. O_2 expresses oxygen demand by heterotrophic activity during the incubation. Black bars express the each original amount. Dotted bars express addition of the element. Shaded bars mean the oxygen demand. The difference between BOD and MBOD is shown in A. The oxygen demand depended on available nitrogen is shown in B. The oxygen demand depended on available phosphorus is shown in C.

Figura 2. *Princípio do método de MBOD (DBO modificada): M expressa micronutrientes. P é o fósforo. C é a fonte de carbono. O_2 expressa a demanda pela atividade heterotrófica durante a incubação. As barras pretas expressam cada quantidade original. As barras com pontos expressam a adição do elemento. As barras hachuradas significam a demanda de oxigênio. A diferença entre a DBO e a DBO modificada é mostrada em A. A demanda de oxigênio dependente do nitrogênio disponível é mostrada em B. A demanda de oxigênio dependente do fósforo disponível é mostrada em C.*

MICROBIAL ACTIVITY IS SENSITIVE TO TEMPERATURE

BOD method was invented to evaluate the polluted canal in London, UK in industrial period. This is the bioassay using the microbial activity. The amount of oxygen consumption during the incubation is proportional to the amount of available organic matter in water. The incubation condition was decided to the 5 day's incubation at 20C in dark. This condition was assumed to evaluate the worst situation of a canal in warm period in London. However, the water temperature of Broa was higher than in London canal. Microbial activity relates to the temperature. The oxygen consumption rate by microbial respiration in high temperature shifts to high rate. The original organic matter in higher temperature condition is consumed up within a short period of incubation. There is a correlation between activity and temperature on BOD assay (Bond & Straub 1973). We noticed we could convert the measured consumption in that laboratory condition of UFSCar to the standard value using the conversion table with temperature and incubation period.

HORIZONTAL AND VERTICAL

Deep lakes have a characteristic phenomena related with the recycle nutrient from the bottom. Rivers, shallow reservoirs and slow sand filter pond have always one direction of water current. The main subject on the traditional limnology has been focused on the stratified structure at the lake center in deep lakes. However, the water in a shallow reservoir is easily mixed entirely by wind action in savanna region in continent. Available nutrients are easily consumed up by organisms in inflow region. Characteristic feature compared with lakes is the longitudinal phenomena along the water course.

OCEAN TO RESERVOIR

I studied on primary production of phytoplankton in the ocean in the graduation course in Japan. I joined in the several survey ships in Pacific Ocean and Atlantic Ocean. I knew phytoplankton worked hard to get extremely low amount of nutrient in the open ocean. I made algal culture study in the laboratory. I studied the relationship of nutrient and algal growth.

Dr. Takako M. Tundisi and Dr. Jose G. Tundisi who worked on oceanographic study in USP moved to UFSCar in 1971. They started to research on reservoir ecology. They learned limnological science in UK.

Reservoirs in São Paulo city had an eutrophication problem with heavy algal bloom. They made a plan to utilize the algal bloom. Their plan was finally the production of the fish protein using the food chain. At first, they thought to get the algal culture technique. They requested an expert to Japan. Then, I came to this country in 1974.

AFTER THAT

After the first visit in 1974, I visited many times to this country by another projects. We made co-operative research on Brazilian limnology. One of my students, Mr. Kozo Hino who was the UFSCar student in 1974 contributed actively between Japan and Brazil.

My main research has been shifted to ecosystem study on slow sand filter. Origin of ecological purification system under hungry condition comes from the Broa ecosystem.

I published a book "How to make delicious water" in Japanese, in 2005. Mr. Hiroyuki Hino, brother of Mr. Kozo Hino, translated this book into Portuguese "Produza Você Mesmo Uma Água Saborosa – Sistema de Puficação Ecológica, Revendo a Tecnologia de Produção de Água Potável". This book was published in 2009, in São Paulo, supported by JICA (Japan International Cooperation Agency) and the association of 100 years' anniversary of immigrant from Japan to Brazil. This book was also translated into Chinese and published in Beijing in 2010. This content has been opened though an internet text in English and in Japanese by JICA in 2009 (JICA 2009). This is the proof of the long friendship between Japan and Brazil from 1974.

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