ชื่อ-สกุล .... รหัสนักศึกษา...

PRINCE OF SONGKLA UNIVERSITY

Department of Civil Engineering

Midterm Exam: First Semester — Academic Year: 2010

Date: 1 August 2010 — Time: 9:00–12:00

Course: 223-541 Pollution Prevention for Environment — Room: S201

Instructions:

1. The exam has a total of 5 problems, 70 points as indicated in the table below.
2. Write your name and student ID on this exam sheet and your answer booklet.
3. Write your answers in the booklet provided and turn it in with this exam sheet.
4. Use of calculator is allowed in the exam room.
5. This is a closed book exam.

ทุจริตในการสอบ โทษขั้นต่ำ ปรับตกในรายวิชาที่ทุจริตและ พักการเรียน 1 ภาคการศึกษา

Sumate Chaiprapat

Problem	Score	Your Score
1	15	
2	10	
3	15	
4	10	
5	20	
Total	**70**	

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1. จงอธิบายขั้นตอนในการทำการป้องกันมลพิษ ในโรงงานอุตสาหกรรมตามหลักการของ Green Productivity และให้ระบุเครื่องมือ (Tools) ที่สามารถนำไปประยุกต์ใช้ในแต่ละขั้นตอนนั้นๆ (10 คะแนน)

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2. ระบบไฟแสงสว่างที่ใช้ในโรงงานแห่งหนึ่งเป็นแบบไม่สะท้อนแสง ประกอบด้วยหลอดฟลูออเรสเซนท์ ชนิด T12 จำนวน 4 หลอด และบาลลาสต์แบบแกนแม่เหล็ก 2 อัน ใช้สวิทซ์เปิด/ปิด แบบธรรมดา โดยแต่ละโคมกินไฟ 192 วัตต์ และมีอัตราการใช้งานเฉลี่ย 3,500 ชม./ปี

ถ้ามีการเปลี่ยนเป็นหลอดไฟประหยัดพลังงาน T8 จำนวน 2 หลอด และบาลลาสต์อิเลคทรอนิกส์ 1 อัน ต่อโคม โดยใช้แผ่นสะท้อนแสงด้วย จนได้แสงสว่างระดับเดียวกับโคมแบบเดิม ระบบนี้กินไฟ 65 วัตต์ และด้วยการติดระบบสวิตซ์แสงเพื่อควบคุมการเปิดปิดเมื่อแสงไม่พอแล้วทำให้อัตราการใช้งานเฉลี่ยลดเหลือ 2,275 ชม./ปี

การปรับปรุงครั้งนี้มีค่าใช้จ่าย 4,000 บาท/โคม (ทั้งค่าวัสดุและค่าแรง)

บิลค่าไฟของบริษัทนี้ดังแนบ จงหา

(ก) ค่าไฟฟ้า (บาทต่อปี) สำหรับโคมไฟระบบ T12 (2 คะแนน)

(ข) ค่าไฟฟ้า (บาทต่อปี) สำหรับโคมไฟระบบ T8 (2 คะแนน)

(ค) ระยะเวลาคืนทุนอย่างง่าย (simple payback period, SPB) ของการลงทุนครั้งนี้ (2 คะแนน)

(ง) ถ้าโรงงานแห่งนี้ใช้โคมไฟ T12 จำนวน 100 ชุด และต้องการเปลี่ยนทั้งหมด โดยให้อัตราส่วนลด (discount rate, i) = 10% ไม่คิดค่าเสื่อมและมูลค่าซาก จงหาว่าอายุของหลอดไฟต้องเป็นประมาณกี่ปีจึงจะคุ้มค่าในการลงทุน (5 คะแนน)

$$\text{Present worth} = \frac{F}{(1+i)^n}$$

(จ) ให้อภิปรายผลเปรียบเทียบข้อ (ค) และ (ง) หากอายุหลอดไฟ T8 = 7,000 ชั่วโมง (4 คะแนน)

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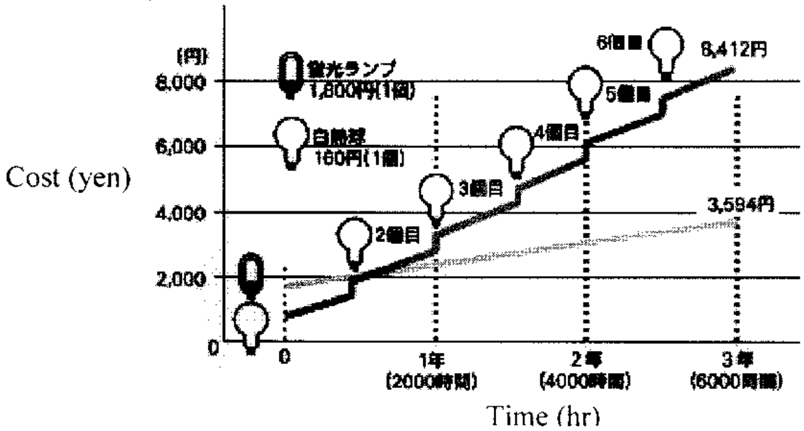
3. โรงงานอาหารแห่งหนึ่งได้ดำเนินโครงการ P2 อย่างจริงจัง โดยมีเป้าหมายเพื่อลดปริมาณสารอินทรีย์ (หรือ loading) สู่ระบบบำบัดน้ำเสีย ซึ่งปัจจุบันมีปัญหาไม่สามารถบำบัดน้ำเสียได้ตามกฎหมายกำหนด ข้อมูลดังตารางข้างล่างนี้แสดงปริมาณ BOD หรือ BOD loading จากกระบวนการผลิตที่เข้าสู่ระบบบำบัดน้ำเสีย ก่อนดำเนินโครงการ (ปี 2004 และ 2005) และหลังดำเนินโครงการ (ปี 2006 และ 2007) คุณคิดว่าโปรแกรม P2 ที่โรงงานนี้ดำเนินการสำเร็จหรือไม่อย่างไร อธิบาย (10 คะแนน)

BOD loading, g/yr = (BOD, g/m^3)(Flow rate, m^3/yr)

Year	Production, tons/yr	Wastewater volume, 1,000 m^3/yr	BOD Concentration, mg/L
2004	800	455	1055
2005	810	465	1097
2006	600	372	968
2007	610	410	1024

หมายเหตุ ควรเปรียบเทียบด้วยดัชนีที่เทียบกับปริมาณการผลิตด้วย

4. รูปที่แสดงข้างล่างนี้ถูกนำมาจากเอกสารภาษาญี่ปุ่นเกี่ยวกับการใช้หลอดไฟแบบหลอดไส้ และหลอดตะเกียบ จงอธิบายความหมายของภาพนี้ (5 คะแนน) และให้เปรียบเทียบการใช้หลอดทั้งสองโดยให้สมมติตัวเลขราคาและค่าใช้จ่ายต่างๆ ในรูปของตัวแปร เช่น หลอดไปแบบตะเกียบมีราคา y บาท/หลอด อัตราการกินไฟ a บาท/ชั่วโมง เป็นต้น แล้วให้สร้างสมการที่สามารถคำนวณหาระยะเวลาที่ทำให้เกิดการคุ้มทุน (จุดที่เส้นกราฟตัดกัน กี่ชั่วโมง กี่บาท) อธิบายประกอบให้ชัดเจน โดยกำหนดให้หลอดไส้มีอายุการใช้งาน 1,000 ชั่วโมง และหลอดตะเกียบ 6,000 ชั่วโมง (10 คะแนน)



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5. โรงงานแห่งหนึ่งทำกิจการแปรรูปปลาทะเล ทำให้เกิดมลสารในรูปของสารอินทรีย์ปนเปื้อนในน้ำเสียสูงมาก และระบบบำบัดน้ำเสียของโรงงานแห่งนี้ไม่สามารถที่จะบำบัดให้น้ำเสียผ่านตามเกณฑ์มาตรฐานตามกฎหมายได้ แทนที่จะ upgrade ระบบบำบัดเค้าต้องการที่จะลดความสกปรกของน้ำเสียนี้ด้วยมาตรการทาง pollution prevention ก่อนที่น้ำเสียจะเข้าสู่ระบบบำบัดแบบเติมอากาศของโรงงาน ในการนี้ทางผู้ประกอบการต้องการที่จะได้แนวทางที่รวดเร็วและมีความน่าเชื่อถือ จงใช้ข้อมูลใน paper ทำการ list วิธีการที่ผู้ประกอบการของเรารายนี้สามารถนำไปใช้ได้ (10 คะแนน) และบอกข้อมูลของแต่ละวิธีที่ paper นำเสนอในรายละเอียดมาอย่างกระชับภายใน 3-4 บรรทัดในแต่ละวิธี (10 คะแนน)

หมายเหตุ ไม่ต้องหาคำแปลสำหรับศัพท์เฉพาะต่าง ๆ

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Pollution prevention and biochemical oxygen demand reduction in a squid processing facility

Eugene Park [a,*], Richard Enander [b], Stanley M. Barnett [a], Chong Lee [c]

[a] *Chemical Engineering Department, Center for Pollution Prevention, University of Rhode Island, Kingston, RI 02881, USA*
[b] *Office of Technical and Customer Assistance, Rhode Island Department of Environmental Management, Providence, RI 02908, USA*
[c] *Department of Food Science and Nutrition, FSN Research Center, University of Rhode Island, Kingston, RI 02881, USA*

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Abstract

Fish processing, especially squid, creates high strength biochemical oxygen demand (BOD) wastewater that must be pretreated prior to sewer discharge. This study evaluated (1) new squid processing techniques, (2) advanced biological/chemical treatment technologies to meet local wastewater discharge regulations, and (3) recycling opportunities for materials formerly discarded as waste. Low technology modifications such as improved housekeeping/management systems were implemented in order to obtain initial reductions in BOD loadings. Various high technology separation processes, aimed at removing soluble BOD from the process effluent, were evaluated. A first order cost–benefit analysis based on capital and operating costs, BOD reduction efficiencies, and worker health risk factors indicated that a modified biological trickling filter was the best available pretreatment technology for squid processing wastewater.

Keywords: Squid processing; BOD reduction; Squid organic recovery

1. Introduction

Rhode Island's commercial fishing industry plays an important role in both the state and region's economy. With the decline in the supply of traditional fish species in the Northeast and the onset of new federal regulations, however, the Rhode Island fishing industry has been in transition to diversify efforts which target under utilized species such as squid. Processing of squid and several types of finfish, which occurs on shore in fish processing facilities, creates high levels of BOD in the wastewater which must be pretreated prior to discharge. Typical BOD readings measured in the effluent of one seafood processing facility ranged from 1000 to 5000 mg/l.

By nature, all fish processing techniques generate by-products and waste. Changes in processing methodologies coupled with increased landings of under utilized species and the desire to expand production, however, have led to dramatic increases in the volume and strength of wastewater discharged by several fish processing companies to the Town of Narragansett's 1.4 million gallon per day (MGD) activated sludge treatment plant [1]. Historically, very little pretreatment had been used since most fish processing wastewater had not been a burden to the local publicly-owned treatment works (POTW). Squid processing, however, was found to result in very high BOD levels which could not be handled by the local POTW. The cleaning, separating, and packaging of under utilized species at these companies has resulted in the generation of a complex mix of solid organic material and contaminated wastewater. For example, squid ink is released into the waste stream during processing and is known to contain high concentrations of organics, including highly soluble proteins, which contribute significantly to excessive BOD loadings [2]. As a result, the town's wastewater treatment facility has been overwhelmed and can no longer accept high BOD loadings from local fish processing operations. A thorough literature search showed that no process had been developed for BOD reduction of squid wastewater at a commercial level.

* Corresponding author. Tel.: +1-401-874-4303; fax: +1-401-222-3810.
E-mail address: epark@earthlink.net (E. Park).

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At the time of this study, a program to implement pretreatment surcharges for excess BOD and total suspended solids (TSS) had already begun and was threatening the survival of three local fish processing companies that had banded together to carry out this project; town limits for BOD and TSS were recently set at 1000 mg/l [1]. Based on loading restrictions and the new surcharges, it was projected that if the companies did not modify their operations, they would not only be unable to expand their operations, but would also be forced to incur significant surcharges and fines or even be required to cease operations.

2. Purpose

A team comprised of representatives from the Narragansett Seafood Processors Association (NSPA), the University of Rhode Island (URI) and the Rhode Island Department of Environmental Management (DEM) collaborated in the examination and demonstration of process modifications aimed at expanded production, reductions in the generation of squid processing wastewater, and the recovery of usable waste solids for new value-added product development. At the outset of this initiative, investigators hoped that by carefully applying selected technologies companies could eliminate added production costs, incurred from disposal surcharges, while at the same time introducing a potential profit-making operation. Researchers anticipated that the results of this project could be applied to other fish processing companies in the region as well as throughout the United States.

The principal focus of our environmental improvement effort was on *pollution prevention*, which is defined by the US Environmental Protection Agency as "the use of materials, processes or practices that reduce or eliminate pollutants at their source" [3]. Overall, our research efforts focused on the reduction of pollutants at their source and improvements in the management of all solid/aqueous waste streams. More specifically, the hierarchy of environmental objectives for this project were as follows: (1) implementation of low-technology modifications (i.e., improved housekeeping and waste stream segregation), (2) reduction in water use leading to a reduction in the volume of wastewater generated per pound of product, (3) installation of low- and high-technology separators to capture remaining wastewaters for organic solids recovery and concentration, (4) characterization of fish processing by-products and organic matter, and (5) the development of a marketing plan to sell recovered by-products and organic matter after appropriate refinement, for example, as an aquatic feed ingredient and flavor additive. Pollution prevention factors affecting the type(s) of separation technology to be used included economics, worker safety and the effect on value-added product recovery from the waste materials. Hazardous materials used in many treatment schemes like chemical treatment were to be looked at for economic comparison but not favored because of worker and plant safety issues. This paper summarizes the research activities undertaken, as they relate to environmental compliance with special reference to by-product recovery.

3. Work performed

3.1. Low technology process modifications for better waste management

The layout of the fish processing facility (Fig. 1) was evaluated for future installation of both low- and high-technology separating equipment. Because of an increased need to meet local compliance levels for wastewater discharge, several low technology process modifications were implemented immediately including better floor drain screens and close supervision/training of production line workers to prevent large body parts of fish from entering the sewer system. Prior to the project, the squid processing techniques used (i.e., separation of unwanted body parts by hand) resulted in large pieces falling onto the floor and entering the sewer lines. Many of the incidents related to non-compliance were

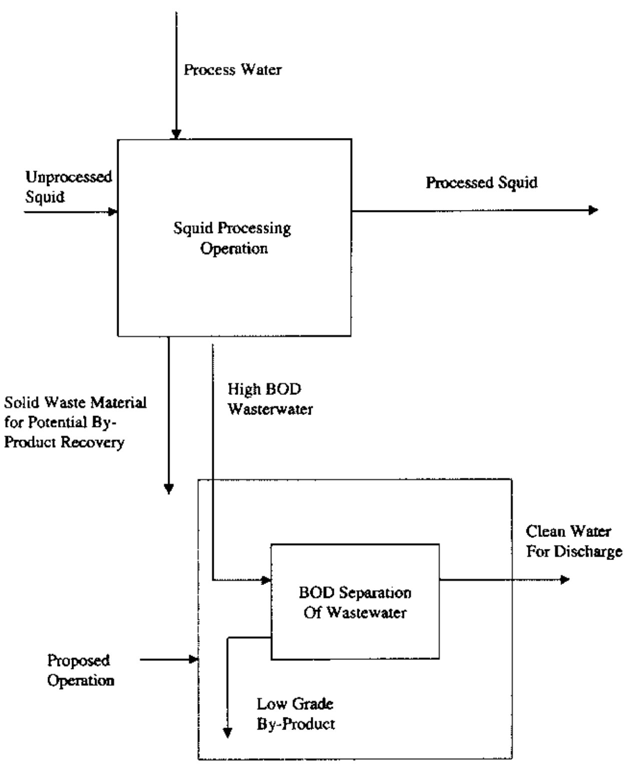

Fig. 1. Squid processing project flow schematic.

because of the discovery of large squid pieces in the sewer system. When the project began, workers were trained to separate and contain discarded pieces. The ink sacs, which are the main source of the high organics concentration, were very difficult to isolate in a mass production environment where many thousands of squid are processed each day.

3.2. Coarse filtration design and implementation

Typical effluent flow rates at the test site were estimated to be 15,000 to 20,000 gallons per day (gpd). Regardless of the ultimate treatment technology selected, the waste effluent had to first be collected and filtered through coarse filtration equipment (100–500 μm). Several available technologies for separating fish solids were investigated including simple cartridge filtration, hydrocyclone [4], and passive filtration. For our application, simple filtration was determined to be not cost-effective due to high filter replacement and labor costs. By comparison, hydrocylones rely on significant differences in densities of the particles and fluid to work efficiently; fish waste materials for the most part are not much more dense than water.

Results of a literature search ultimately led project team members to a fish processing facility that uses coarse passive filtration. Though not exactly similar in application (that facility was not concerned with BOD), the physical design of piping, sumps and coarse filtration equipment could be applied to any fish processing facility. The equipment used to remove coarse solids included a passive filtration system which resembles a playground slide where the feed water is introduced at the top and flows down an inclined, perforated (with holes of the desired separation size) metal surface. Solids are retained above the surface while the filtrate passes through. The separated solids eventually slide down to the bottom, are collected and removed periodically.

Using passive coarse filtration technology, most of the solids leaving the process lines can be captured. Solids loadings to the local POTW, therefore, can be reduced significantly while BOD reductions of about 25% are achieved. The recovered solid materials from the unit are then available for further processing into a saleable material. While this type of coarse filtration technology for solids removal is well established in the seafood industry, less was known about the optimum technology for managing high BOD, soluble squid waste.

3.3. High technology separation (BOD removal)

As the majority of participating companies located in Galilee are involved primarily in squid processing, much of the research and testing of high technology separators was centered on this type of waste. When the project originally began, it was believed that membrane filtration (see Results) would be the technology of choice based on preliminary data obtained before this grant project started; other technology testing had not been conducted at that time. Earlier research conducted by Green et al. revealed that a feasible process using ultrafiltration could be developed to handle soluble waste from minced fish production [5]. Membrane tests conducted on squid processing waste in Galilee, however, did not produce satisfactory results. Marti et al. also found that ultrafiltration was not cost-effective to separate proteins from fishmeal wastewater [6].

Alternative technologies were considered and tested either at the fish processing company or at an outside facility using wastewater generated from the company. The technologies investigated included: (1) anaerobic biological treatment, (2) ozone treatment, (3) dissolved air flotation, (4) membrane filtration, (5) electrocoagulation, (6) chemical treatment and (7) biological trickling filtration. Each technology was either tested alone or combined in a dual step process. For example, chemical treatment was combined with dissolved air flotation to achieve significant BOD reductions; a two-step process using membrane technology and biological trickling filters was also considered. Pilot study findings and the data used to select the final process can be found in the Results section. Criteria to evaluate processes included BOD reduction capability, capital and operating costs, and worker safety. Comparative evaluations were supported by first order analyses of processes that were commercially available at the time of this study; time and funding constraints did not allow for an exhaustive vendor search and test program.

3.4. Product development work

Under the direction of the Food Science Department at URI, various by-product recovery studies were carried out which included the development of flavorings, aquaculture feed ingredients, squid mince and fertilizer; other researchers also investigated recovery techniques from various fish and seafood processing wastes [6,7]. While some mention of these activities are made in this paper, the *technical* details of the work performed on by-product recovery from squid waste can be found in the final project report submitted to NOAA [8].

4. Results

As described in the previous section, low technology solutions such as improved processing techniques (better handling of waste and housekeeping) and drain screens were implemented immediately. These measures had little effect on the actual BOD levels since the soluble organics, not large solid pieces, contributed to the BOD. The prevention of these squid parts from entering the sewer system did help to alleviate some of the regulatory pressure during the initial phases of the project. For almost two years, various high-technology separation processes were tested on fish processing wastewater comprised mostly of squid. Testing was performed by selected vendors and by the authors.

Test results for each technology are described below. Some scenarios are presented in single stage, others in a multi-stage format.

4.1. Anaerobic biological treatment

Anaerobic biological treatment has been used to treat high BOD/COD waste solutions in a variety of applications [9–12]. Tests performed by a vendor of anaerobic treatment equipment on high BOD squid wastewater indicated that significant reductions in BOD could be achieved (80% reduction) with a high rate upflow sludge blanket system. Capital equipment costs for this technology was quoted at $490,000 to handle 25,000 gpd. Operating costs were estimated to be $45,000/year. It appeared that the process was fairly complex with requirements of possible chemical pretreatment and special handling of a methane by-product. The costs for using this technology ranked high as compared to the other technologies tested.

4.2. Ozone treatment

Ozonation has been used to treat a variety of wastewater streams and appears to be most effective when treating more dilute types of wastes [13]. Since wastewater from squid processing operations is fairly concentrated, ozone would be best applied as a polishing step. One vendor recommended the use of a certain type of anaerobic technology in conjunction with ozonation. However, initial tests performed revealed a maximum achievable reduction of only 40% which would not allow the fish processors to meet the local sewer discharge ordinance. Initial capital costs were quoted at $190,000 with annual operating costs of $40,000. To achieve greater reductions in BOD, it was believed that the anaerobic stage of the process would have to be expanded; costs would increase significantly, perhaps close to that estimated by the anaerobic treatment vendor mentioned above.

4.3. Dissolved air flotation

Dissolved air flotation [14], or DAF, has been in existence for many years and has been proven to remove contaminants from wastewater through chemical addition and air bubble technology. While the technology would undoubtedly work, uncertainty associated with long-term operating costs (capital costs were estimated at $100,000) and potentially recoverable by-products existed. Bench-top studies conducted by two different DAF companies indicated that because the squid wastewater is so high in soluble BOD, the amount of chemicals needed to reduce the BOD by 40–50% would cost the company approximately $600/week ($30,000/year). In order to meet compliance standards, additional treatment chemicals would be required thereby raising chemical replacement costs even more; this approach also went against the pollution prevention goal stated earlier. If additional operating costs such as labor and energy were taken into account, annual operating costs would easily exceed $70,000.

4.4. Chemical treatment

Chemical treatment technologies were mentioned above as being used in conjunction with dissolved air flotation. In many cases, chemical treatment alone is used to remove contaminants from wastewater. Usually, pH-adjustment and the addition of flocculants are carried out. Most flocculants are inorganic but a literature search indicated that "chitosan", a natural-forming flocculent from the shells of certain shellfish, could be used to remove organics that cause high BOD levels [15]. The advantage of using chitosan is that the recovered sludge, which precipitates out, may be used for other applications due to its true organic nature. However, operating costs (including those associated with sludge disposal) for any type of chemical treatment system are high. In addition, there are some safety issues to contend with since hazardous chemicals may be used such as acids, caustics, or ferric chloride.

4.5. Electrocoagulation

Electrocoagulation (EC) was also investigated as a possible means to reduce soluble BOD. EC has been demonstrated to reduce organic levels in various food and fish processing waste streams [16]. An electric charge is passed through a spent solution in order to destabilize and coagulate contaminants for easy separation. The results of initial testing at the test site were favorable in that a sample of brownish squid wastewater was quickly clarified with a small EC test cell — contaminants coagulated and floated to the top. Analytical test results showed some reduction in BOD, but not as much as originally anticipated when the pilot test was conducted. Additional testing was carried out on site on a series of grab samples; however, these runs did not appear to be as effective as originally anticipated. The pH was varied to try to optimize the process, but BOD reductions of only 21–33% were observed. Also, since metal electrodes (aluminum) are used in the process, the presence of metal in the spent solution and separated solids were a potential concern for by-product recovery. Initial capital outlays and anticipated operating costs were not unreasonable ($140,000 and $40,000, respectively), but satisfactory BOD reductions could not be achieved easily. In order to make EC work effectively, very long retention times would be needed.

4.6. Membrane filtration

A major advantage of membrane filtration over other technologies is that chemicals are not added to the process and, therefore, equalization (including extra monitoring and process control) is not required. Also, since the solution is not chemically altered the concentrated squid/fish proteins are more readily recovered for further processing.

The concentrated proteins from the squid processing line presented an unusually high BOD problem — 5000–10,000 mg/l in the waste stream; the BOD of the combined plant effluent was measured to be lower, 1000–5000 mg/l. All membrane testing was performed on the more concentrated squid processing waste. Preliminary tests were run to determine optimum membrane type(s). Single stage membrane tests using ultrafiltration and nanofiltration membranes did not reduce the BOD as much as originally anticipated; e.g., small-scale testing with a pilot ultrafiltration system (0.005 μm pore size membrane) provided higher-than-acceptable BOD levels in the permeate. While the membranes tested produced a clarified solution, there were still unacceptably high levels of BOD (in the 2000–4000 mg/l range) indicating that smaller sized proteins and other organics were passing through the membrane. A tighter (0.002 μm) membrane provided cleaner permeate (or filtrate) in the 1500–2000 range, but the permeate flow rates were lower and would thus require a higher initial capital investment and subsequently, higher operating costs.

Tests were also carried out to determine the effectiveness of reducing BOD with a two-stage membrane system. Permeate from the first ultrafiltration membrane step was collected and then fed to another, much tighter nanofiltration membrane. Process characteristics that were evaluated included flux (permeate flow) and BOD reduction. From an average of several test runs, BOD was reduced from approximately 4000 mg/l to 2000 mg/l (50% reduction) with a 0.005 μm ultrafiltration membrane. The nanofiltration membrane further reduced the BOD down to approximately 300 mg/l, an overall reduction of over 90%.

In any membrane process, the concentrate streams must also be managed accordingly. In this particular application, the concentrate consisted of high BOD organics that had been separated by the membrane. The volume of concentrate was estimated to be approximately 5% of the total volume treated. For example, if 20,000 gpd of wastewater are treated daily as influent to the process, 19,000 gpd of clean water (or permeate) and 1000 gallons/day of concentrate will be produced. Possible uses of the concentrate included further processing for fertilizer and secondary treatment with other technologies such as evaporation or biological treatment. Further testing and analyses would be required, however, to determine the cost-effectiveness of such a dual-stage membrane process.

4.7. Biological trickling filter

While biological treatment technologies have been used in many different BOD reduction applications (e.g., sewage treatment), overall costs associated with the purchase and operation of most biological treatment systems such as activated sludge are far too high for most industrial applications. Recent developments that make use of both anaerobic (discussed above) and aerobic treatment have allowed certain industrial applications to become more cost-effective. In Rhode Island, a company called BioProcess Technologies has developed processes that allow effective treatment of high BOD wastewater. Specially designed netting materials are used in the BioProcess system for the attachment and growth of microorganisms needed to digest and reduce organics in the wastewater.

In standard activated sludge treatment systems, microorganisms are suspended in solution and large tank volumes are needed to manage sludge. By comparison, the netting material used in the BioProcess system can be characterized as a "fixed film" or "attached" type of biological treatment; the configuration used can either be in a submerged mode where underwater aeration is provided for oxygen transfer or free standing where wastewater is trickled down through the netting material. Although testing was performed in the submerged mode with encouraging BOD reductions, the high efficiency of microbial growth on the polyvinylchloride material necessitated much higher oxygen transfer requirements which were difficult to maintain in the pilot test set-up. It was then decided to focus on a trickling filter configuration (where the water is sprayed into an open area) that does not require artificial oxygen transfer. The increased retention times of the microbial sludge in fixed film reactors also results in a larger population of microbes, which consume organics more efficiently than the bacteria typically found in conventional, suspended growth systems [17].

Initially, waste squid solution was fed into a small, pilot-scale trickling filter with a built-in recycling pump and spray nozzles. Calculated results of feed rate (loading rate) vs. % BOD reduction are shown in Table 1. The results indicate that the trickling filter design can take loadings of up to 3.5 lb. BOD/1000 ft media/day and still reduce the BOD by 87%. Other kinetic parameters of interest that were experimentally derived included the cell yield coefficient (0.62 lb cells/lb of BOD) and the cell death rate (0.011 lb cell death/lb cell

Table 1
Rope media trickling filter results

Application rate (lb BOD/1000 ft of media/day)	% BOD reduction
0.93	98
2.01	84
3.47	87

present/day). Comparison of these results to developed models on biological treatment showed several inconsistencies, indicating that some inhibiting factor was affecting the kinetics of the process. Nevertheless, the initial testing provided enough information to explore full-scale implementation of a single technology, namely, biological trickling filtration.

Upscale design of the trickling filter using data of 15–20,000 gpd of wastewater with BOD in the 2–3000 mg/l range indicated that 200,000 linear feet of media in 4–6 reactor tanks would be required. The calculations took into account a large safety factor. However, as will be discussed in the next section, a smaller size system was initially installed.

4.8. Technology comparison and implementation

A first-order economic analysis was carried out on all technologies investigated. While an exhaustive study of each process was not undertaken, enough information was obtained to make sound technology comparisons. In addition to initial capital costs and estimated operating expenses, safety/risk factors and potential by-product recovery opportunities were examined. For example, while chemical treatment technology necessarily requires the use and handling of toxic materials (posing potential health risks to workers), by-product recovery opportunities for chemically treated materials are somewhat limited. The biological trickling filter system piloted at the company provided the highest BOD removal efficiencies with the lowest operating costs and minimal worker risk of all the technologies tested. While potential by-product recovery from this technology is limited to perhaps only fertilizer, it was determined that POTW compliance was a much more important issue since regulatory pressure was steadily increasing to the point that the livelihood of the fish processing industry was in jeopardy. As a result, other factors like capital and operating costs played a more important role than the potential for organics recovery in the determination of the best BOD removal process. The trickling filter system provided between 90 and 98% BOD removal based on *Lolligo pealei* squid wastewater with an initial 2500 mg/l BOD concentration and a 500 mg/l total suspended solids (TSS) concentration. Design of the full-scale system was based on a BOD loading rate of 2 pounds of BOD per linear foot of media per day at 20,000 gallons

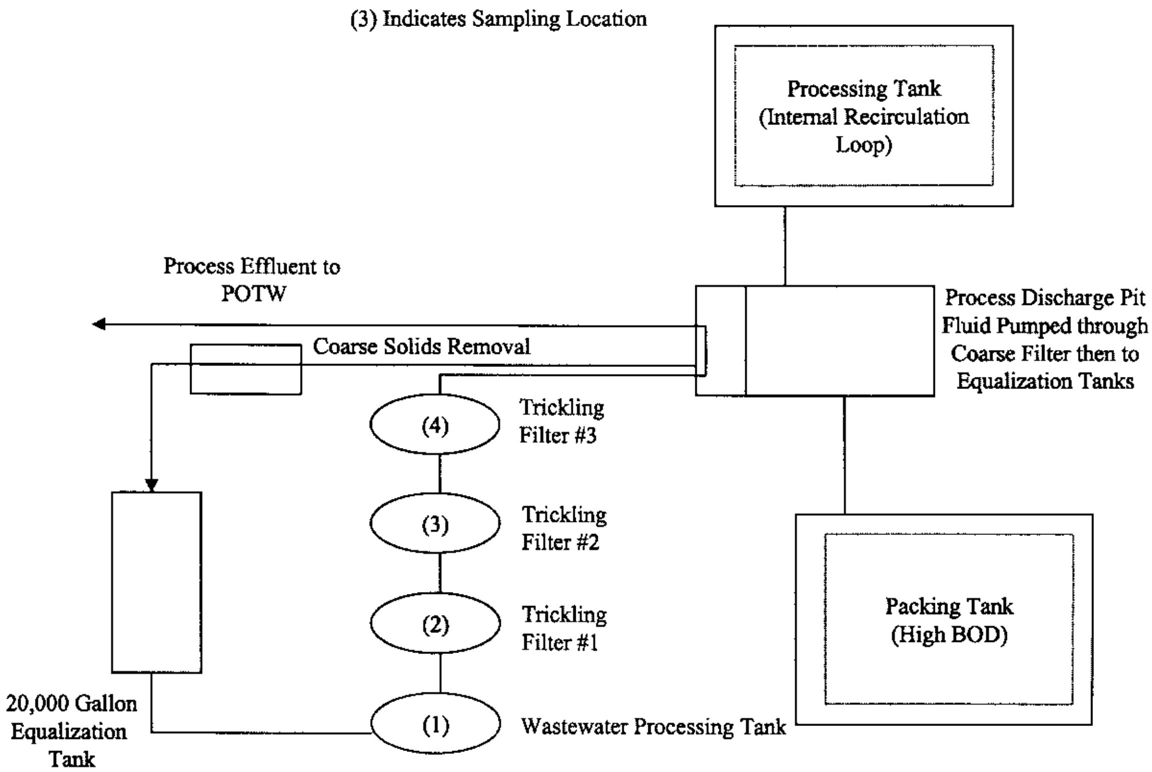

Fig. 2. Squid processing BOD removal.

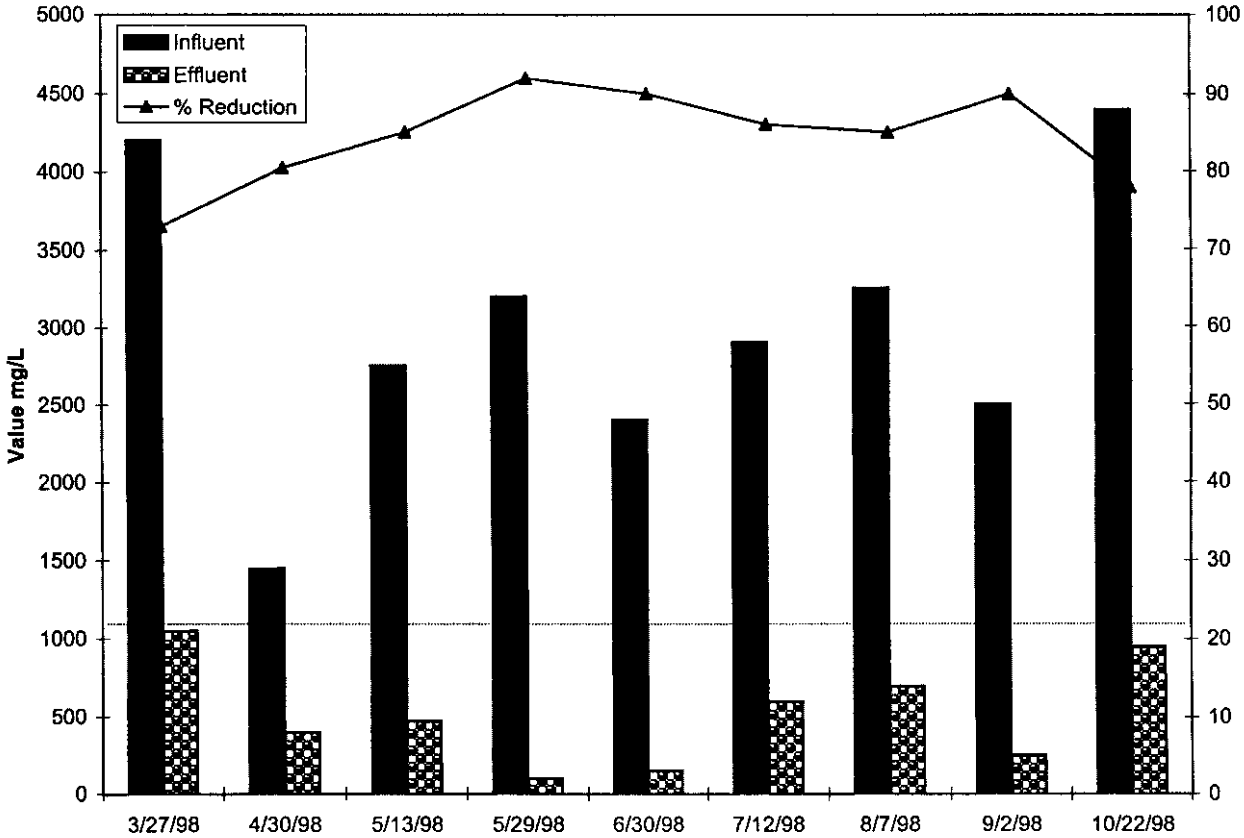

Fig. 3. Squid processing BODs influent/effluent data for 27 March–22 October 1998. Analysis performed by RI Analytical Lab and/or ESS Labs. July analysis was performed by BMT.

per day average flow, requiring a total of 200,000 linear feet of media.

The total cost of 8 trickling filter towers with 200,000 linear feet of media was quoted at $169,000. Because of project budget constraints and limited available space at the company, it was decided to initially install half the required treatment process (100,000 linear feet of media in 3 reactors) in order to monitor scale-up performance prior to expansion. The mind set at this point was that a smaller sized system might still fulfill compliance requirements, or at the very least reduce loadings significantly to the point where local regulatory authorities would be satisfied with the progress made.

In August of 1997, three reactor tanks with a total of 100,000 linear feet of media were installed with the necessary piping and pumps. A 20,000 gallon equalization tank was also added to help normalize incoming flows; heating elements were installed in the reactor tanks shortly thereafter. The flow schematic/layout of the operation is shown in Fig. 2. Sampling was carried out at various points in the process from August 1997 to October 1998. Initially, flow rates were steadily increased over a period of several weeks to the peak capacity of approximately 20,000 gpd. Inconsistent results, observed until the Spring of 1998, were attributed to the sporadic hydraulic overloading of the system and cold temperatures (before the 20,000 gallon equalization tank was installed and heating elements added).

Though the overall wastewater generation rate was ~20,000 gpd, the wastewater would enter the system periodically at very high flow rates due to fluctuations in the fish processing schedule. Total suspended solids (TSS) in the discharge water were also evident. While the process is described as "attached" growth to the nylon netting, some suspended material (~20% of traditional suspended growth systems) still existed due to cell death, metabolic waste, and incidental mechanical abrasion. As a result, higher total BOD readings over soluble BOD readings were observed. A settling tank was added as a solids removal step after the last trickling tower to further reduce BOD levels even more. Total BOD results of the final effluent from March to October 1998 are shown in Fig. 3.

While the target BOD effluent goal was <1000 mg/l, the system initially installed was one-half the size of the original design and hence could not guarantee that target levels would be met consistently. If the correct size system is implemented, however, the project team believes that BOD levels would consistently meet discharge regulations.

4.9. Product development

Solid waste materials from squid processing and waste treatment come in two forms: (1) body parts (head, arms and tentacles) from processing and (2) separated waste from the BOD removal process. In Fig. 1, the two waste streams are noted as "Solid Waste Material for Potential By-Product Recovery" and "Low Grade By-Product". All of the research carried out by URI Food Scientists focused on the first type, processing waste. Typically, this waste is transported to a landfill as non-hazardous waste. Squid tissue has unique physical and biochemical characteristics which offer opportunities for specialized recovery products [18,19]. Research studies have indicated that the following potential value-added commodities can be produced from waste squid body parts: (1) squid mince for extruded products, (2) flavorings, and (3) aquaculture feed.

Production schemes for the potential products can be seen in Fig. 4. Re-processed squid products like fish nuggets can be created after a series of grinding, mixing and extrusion steps. Hydrolysis of the squid parts can also result in concentrated flavorings, both liquid and powder, which can be used as flavoring ingredients for human consumption or mixed with other materials to produce commercial-grade aquaculture feed for fish in aquaculture farms. From amino acid profile analyses conducted at URI, the squid hydrolysate appears to have an amino acid make-up that is considered good for use as a feed attractant and is better digested by fish than traditional fish meal. While more research is needed to continue the efforts described above, preliminary indications are that viable value-added products can be produced.

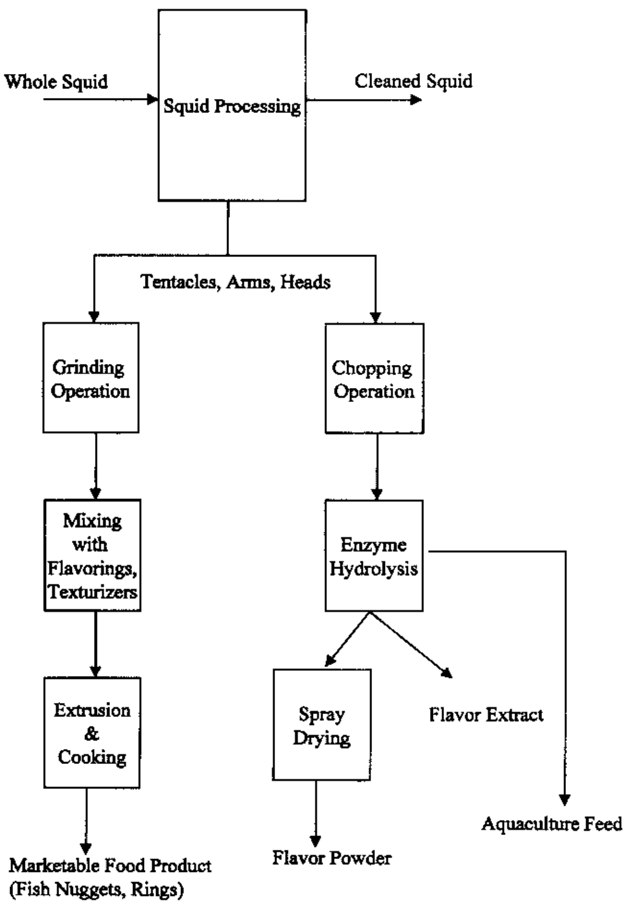

Fig. 4. Value-added products from waste squid parts.

The other type of waste that needed to be addressed came from the BOD separation process used on the wastewater (Fig. 1). As mentioned in earlier sections, one factor affecting the determination of the best BOD separation process was the recoverability of useful by-products. Due to regulatory pressure, economics were more important than recovery potential. Testing conducted throughout the project demonstrated that regardless of the technology chosen, separated solids or liquid from the treatment process would at best qualify for low grade products such as fertilizer.

The final effluent from the squid processing lines contained washwater and floor drainage which were not high grade materials for the making of value-added products. Since the solids removed from the BioProcess process consisted mainly of dead microbial matter and waste metabolic products, it was believed that usable organic fertilizer-type material could be recovered. Other technologies such as chemical treatment would result in excessive amounts of unusable sludge. Studies are underway to determine the market potential of the BioProcess sludge for fertilizer use.

5. Conclusion

Wastewater from squid processing, a high BOD waste stream, is difficult to treat with simple measures. Because of the high levels of organics, microbial degradation appears to be the most effective technique available. Of the various biological processes investigated, a fixed-film system emerged as the most cost-effective technology for this application.

Acknowledgements

Pilot testing and research for this project was carried out at a local fish processor in Galilee, Rhode Island. The US Department of Commerce, National Oceanic and Atmospheric Administration and the Rhode Island Department of Environmental Management, Office of

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การไฟฟ้าส่วนภูมิภาค

200 ถนนงามวงศ์วาน เขตจตุจักร กรุงเทพฯ 10900

<u>หนังสือแจ้งค่าไฟฟ้า</u>

ที่ มท 5305.94/สจ.สรข.002

สำนักงานการไฟฟ้า........................

วันที่ 03 เดือน มกราคม พ.ศ. 2551

เรื่อง แจ้งค่าไฟฟ้า

เรียน บริษัท จำกัด

การไฟฟ้าส่วนภูมิภาค ขอแจ้งค่าไฟฟ้าของท่านซึ่งจดหน่วยวันที่ 31/12/50 รหัสการไฟฟ้า 12-04-2-01

หมายเลขผู้ใช้ไฟ........ ประเภทอัตรา 40 แรงดัน 22-33 KV ตัวคูณ 1800.0000

เป็นค่าไฟฟ้าประจำเดือน ธ.ค. 2550 ใบเสร็จรับเงินเลขที่ ฎ 9943006 ตามรายละเอียดต่อไปนี้ :-

ค่า กิจการผลิต 0.7263 กิจการระบบส่ง -0.0241 กิจการระบบจำหน่าย -0.0411 รวม 0.6611 (บาท/หน่วย)

		เลขอ่านครั้งหลัง	เลขอ่านครั้งก่อน	กิโลวัตต์/หน่วย/กิโลวาร์
พลังไฟฟ้าสูงสุด (กิโลวัตต์)	P	3.225	2.920	
	OP	3.019	2.743	
	H	3.149	2.855	
พลังงานไฟฟ้า (หน่วย)	P	633.670	581.500	
	OP	468.550	426.620	
	H	467.390	425.460	
กิโลวาร์		1.890	1.708	

DC = บาท

EC = บาท

		ระบบผลิต (บาท)	ระบบส่ง (บาท)	ระบบจำหน่าย (บาท)
ค่าพลังไฟฟ้าสูงสุด	P			72978.57
ค่าพลังงานไฟฟ้า	P	186797.88	66278.85	
	OP	222729.85		
ค่า Ft				
รวม				

	จำนวนเงิน (บาท)
ค่าบริการรายเดือน 228.17 บาท ได้รับการอุดหนุน 0.00 บาท / ค่าไฟฟ้า + ค่า Ft	228.17
ได้รับ(-)/ให้(+) การอุดหนุนค่าไฟฟ้า	
ค่าเพาเวอร์แฟคเตอร์	
ปรับปรุงเพิ่ม / ลด	
อื่นๆ	
0.00 รวมเงินค่าไฟฟ้า	
ภาษีมูลค่าเพิ่ม 7 %	
รวมเงินที่ต้องชำระ	

หน่วยที่คิดค่า Ft หน่วย

รวมเงินที่ต้องชำระ (เจ็ดแสนแปดหมื่นหกพันหนึ่งร้อยสิบสามบาทแปดสิบห้าสตางค์) 786113.85.-

จึงเรียนมาเพื่อโปรดกรุณาชำระเงินจำนวนดังกล่าวให้กับการไฟฟ้า ภายในวันที่ 17 มค 51 จักขอบคุณยิ่ง

ขอแสดงความนับถือ

(ลงชื่อ)........................

(........................)

ตำแหน่ง ผู้จัดการ

<u>หมายเหตุ</u>

1. โปรดชำระเงินตามจำนวนข้างต้นภายใน 15 วัน หรือตามข้อตกลงนับจากวันที่รับหนังสือแจ้งค่าไฟฟ้า
2. เมื่อชำระเงินตามจำนวนข้างต้น ต้องเรียกใบเสร็จรับเงินทุกครั้ง มิฉะนั้นการไฟฟ้าส่วนภูมิภาคจะไม่รับรองว่าได้ชำระเงินถูกต้องและใบเสร็จรับเงินนั้น ต้องมีลายมือชื่อของพนักงานเก็บเงินหรือผู้รับเงิน

ได้รับหนังสือแจ้งค่าไฟฟ้าแล้วเมื่อวันที่........................

(ลงชื่อ)........................ ผู้ใช้ไฟฟ้าหรือตัวแทน

(........................)

โทร........................