Title: The importance of Cheung Ek Lake, Cambodia: socioeconomic value and negative impacts

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អត្ថបទសង្ខេប

បឹងជើងឯក មានទីតាំងក្បែររាជធានីភ្នំពេញជាកន្លែងស្តុកកាកសំណល់នៃទីក្រុង និងរោងចក្រឧស្សាហកម្មមកពីជាយក្រុងភាគនិរតី និងភូមិជាច្រើនស្ថិតនៅតំបន់បឹងនេះ (ច្រើនជាងមួយពាន់ហិកតា)។ កាកសំណល់ទាំងនេះមិនត្រូវបានចម្រោះ និងបានដាក់បញ្ចូលគ្នាជាមួយការអនុវត្តន៍កសិដ្ឋានដែលស្ថិតនៅជុំវិញមាត់បឹង ហើយកំពុងតែគំរាមកំហែងដល់សុខុមាលភាពមនុស្ស និងសេដ្ឋកិច្ចនៃតំបន់នេះ។ ទោះបីសកម្មភាពកសិកម្មផ្តល់នូវសារៈសំខាន់នៃសេដ្ឋកិច្ច ដោយភ្ជាប់ទៅនឹងទីផ្សារ និងស្បៀង ក៏ប៉ុន្តែកំពុងតែបង្កើននូវការព្រួយបារម្ភសម្រាប់សុខុមាលភាពជាប់ទាក់ទិននឹងការអនុវត្តន៍ទាំងនេះ។ កាកសំណល់រួមមាន លោហធាតុកម្រិតធ្ងន់សរីរាង្គកខ្វក់ សារធាតុចិញ្ចឹមរលាយក្នុងទឹក និងកាកសំណល់ជីវសាស្ត្រសកម្មដែលកំពុងតែហូរចូលទៅក្នុងបឹងជារៀងរាល់ឆ្នាំ ជាមួយការបន្សាបជាកត្តាតែមួយគត់ក្នុងការជួយបន្ធូរបន្ថយ។ ទឹកកខ្វក់នេះ បានបង្កស្ថានភាពដ៏មានគ្រោះថ្នាក់សម្រាប់សង្គមសេដ្ឋកិច្ចនៃបឹងជើងឯកដូចជា ផលប៉ះពាល់អវិជ្ជមានលើសុខភាពមនុស្ស និងស្ថានភាពសេដ្ឋកិច្ចនៃការអនុវត្តន៍កសិកម្មដែលទើបតែចាប់ផ្តើម។ ការជាប់ទាក់ទងមានពីរ (i) សម្រាប់បុគ្គលផ្ទាល់-ការចំណាយខ្ពស់លើតម្លៃព្យាបាល (ii) សម្រាប់សហគមន៍-ការជួយបន្ធូរបន្ថយនូវសុខភាពខ្សោយ ជំងឺឆ្លង បានផ្សារភ្ជាប់ជាមួយចំនួនច្រើនកំលាំងពលកម្ម ដែលមានសុខភាពមិនល្អសម្រាប់រួមចំណែកទៅលើវិស័យសេដ្ឋកិច្ច។ យើងស្នើសុំលើកនូវវិធីសាស្ត្រសាមញ្ញ ដោយដាំរុក្ខជាតិជួយបន្សាបទឹកកខ្វក់ដែលគួរតែចាប់ផ្តើមឱ្យបានឆាប់ដើម្បីកាត់បន្ថយ សារធាតុបង្កជម្ងឺ និងភ្នាក់ងារចម្លងរោគ នៅក្នុងទឹកកខ្វក់ដែលហូរចូលទៅក្នុងបឹងជើងឯក ជាមួយការបន្ថែម និងការពង្រីកសម្រាប់ប៉ុន្មានឆ្នាំចុងក្រោយនេះ។ ប្រសិនបញ្ហាទាំងពីរនេះត្រូវបានដោះស្រាយ និងគោលនយោបាយរឹតបន្តឹងលើកាកសំណល់សម្រាប់រោងចក្រឧស្សាហកម្ម កសិកម្ម និងសហគមន៍ទីប្រជុំជននោះនឹងបានទទួលនូវផលវិជ្ជមាន លើសុខភាពសេដ្ឋកិច្ចសង្គម និងភាពរីកចម្រើននៃតំបន់នេះ។

Abstract

Cheung Ek Lake, near Phnom Penh, receives a considerable volume of industrial and municipal waste from the southern suburbs and villages in the lake region (more than a thousand hectares). This waste is not treated, and combined with the farming practices conducted on the lake margins, is threatening the human and economic health of the area. Although the agricultural activities provide a vital economic link to food markets, there is growing concern for the health implications of this practice. Waste, including heavy metals, organic pollutants, dissolved nutrients, and biologically active agents are entering the lake throughout the year, with dilution as the only mitigating factor. This wastewater constitutes a dangerous situation for the socio-economic importance of Cheung Ek Lake, as negative effects on human health and economic viability of agricultural practices begin to appear. The implications are two-fold: (i) for the individual - the high cost medical bills and (ii) for the community - the mitigating problems of poor health and disease epidemics, compounded by a workforce containing significant numbers of people too unwell to contribute to the economy. We propose a simple wastewater treatment plant that will immediately start to reduce the pathogens and contaminants in the wastewater entering Cheung Ek Lake, with additions and expansions for later years. If coupled with clear and stricter policies on waste for industries, agriculture and urban communities will see a positive impact on the socio-economic health and wealth of this region.

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Introduction

General information about Cheung Ek Lake

In Phnom Penh, about 90% of all untreated urban wastewater is discharged to wetland areas and lakes, where it is estimated that 20% of vegetables consumed in Phnom Penh are grown. (Muong,2004). Cheung Ek Lake, a seasonally inundated lake located about 5 km to the south of Phnom Penh, receives large amounts of untreated wastewater from urban development (~500,000 inhabitants). Water from the lake eventually flows into the Tonle Sap River. The total surface of the lake is about 1400 ha in the dry season. Cheung Ek Lake is bordered by two districts in Phnom Penh and one district in Kandal province and supports 36 village communities. There are 31 villages located in five Sangkats of Meanchey and Dangkor district, and another five villages are located in four communes of Takmao district. In 2008, there were about 14,380 households living around this lake.

In Phnom Penh, Beoung Cheung Ek is a large water body that receives 80% of the wastewater from Phnom Penh's urban population and from industrial factories (garment and various other factories); moreover, rainfall run-off discharges into the lake (Seyha and Tuan Anh 2004). The lake also receives wastewater from two Boeng Tompun and Boeng Trabek canals. Boeng Trabek pumping station was constructed in 1986 and Boeng Tompun was constructed in 2004 by **Japan International Cooperation Agency** (**JICA**). Cheung Ek Lake is an important area for growing aquatic plants and fish production, and harvesting is undertaken throughout the year.

Methods

This work was done using both all the available secondary data on Cheung Ek and its related information and direct observation with semi-structured interviews of the key people working on the lake. This was in order to understand the overall situation the lake and to propose suitable solutions to overcome the long-term negative impact received from the lake if people keep continuing draining the lake and taking no action on this. This review also serves as a basic reference for policy decision-makers in implementing future development plans on this lake region.

Results of the study

Socio-economic value of Cheung Ek Lake

Cheung Ek Lake represents not only a source of income for more than 400 households living directly around the lake (Kuong *et al*. 2005), but also the 'end point' for Phnom Penh's wastewater. Water spinach (*Ipomoea aquatica*) is the major crop grown in the lake. People also plant water mimosa (*Neptunia oleracea*), water dropwort (*Oenanthe aquatica*), and

Figure 1. Aerial photo of Cheung Ek Lake taken in 2009 (Source: Prof. Puy Lim).

dry season rice (*Oryza sativa*). Aquatic plants, especially water spinach and water mimosa, occupy about a half of the total surface of the lake in the dry season.

The cultivated vegetable (water spinach) is used for human food and also for animal feed. The upper part of the stem and the upper leaves with leaf stalks are used for human consumption, whereas the lower part of the plant with leaf, stem and root may be used as pig feed (Anh *et al*. 2004). The socio-economic activities on the surface of Cheung Ek Lake represent an important source of income for many households around the lake (Balmisse and Sylvain 2003). Moreover, these aquatic vegetable production systems in peri-urban Phnom Penh provides many benefits, not just incomes for producers and low cost wastewater treatment, but also the employment and earning opportunities for many seasonally hired labourers engaged in setting up, maintenance and harvesting of plants. It is also known that the aquatic plant cultivation and fishing activity are performed directly on the lake with waste polluted water; thus human health and economic value of the products may be influenced negatively by these activities.

The farmers usually sell their products at roadside stalls or sell them to wholesalers or collectors. Various middlemen are important links in this market chain. They can collect aquatic products from farmers, transport and then sell them to the wholesalers in both suburban and peri-urban areas. Wholesalers are a key component in the relationship between the collectors and retailers, whilst retailers provide a vital link between wholesalers/collectors and the consumers. Wholesalers are the main customers of collectors and they mainly sell the product to retailers. From survey results conducted by the authors (Sar et al., 2010), there were three main markets for water spinach and water mimosa production: Deumkor, Chbar Ampov and Neak Meas markets. The producer can either sell the product to middlemen or sell it directly at the market. The product is transported by the middleman or producer to the wholesalers in some main markets in Phnom Penh. Then, the wholesalers sell the product to retailers from other markets in Phnom Penh and also to other traders from provinces such as Koh Kong, Sihanukville, and Kampong Cham. Finally, the product is sold to consumers for their daily household diet. The transaction cost of water spinach from producer to consumer is on average 900 riels per bunch whilst it is on average 1,600 riels per kilogram for water mimosa. The prices of both water spinach and water mimosa are higher in the dry season than in the wet season. The farmer receives the highest price between November and December, the period when water spinach and water mimosa can be seriously damaged by insects and diseases and the supply of water spinach is very low. Within the dry season, the direct-use value of Cheung Ek Lake was estimated at more than 1 million USD, of which water spinach production contributed 65%, fishing 20%, water mimosa production 13%, duck raising 1%, and dry season rice production 0.7%. Cheung Ek Lake thus provides economic returns to both (i) the direct beneficiaries (the households who work on the lake) and (ii) the indirect beneficiaries (such as wholesalers, retailers, and middlemen), whilst providing members of the general public with a variety of sources for food security.

In a survey of households that work on Cheung Ek Lake (a case study conducted by Production in Aquatic Peri-Urban Systems in Southeast Asia (PAPUSSA)) found that farmers were concerned about the future water spinach farming in peri-urban areas, especially Beoung Cheung Ek, because the government may decide to develop the lake area for other urban growth purposes (Kuong *et al*. 2005). The farmers fear that this might lead to a number of detrimental effects.

Negative Impacts of Cheung Ek Lake

Cheung Ek Lake water quality may be the source of negative economic and public health impacts for the people living around, and eating the products, from the lake. Untreated wastewater draining into the lake and the direct application of fertilizers and chemical pesticides on the lake for water spinach cultivation all may have negative impacts on water quality.

Wastewater compositions

Wastewater is characteristically grey in appearance, with a musty odour, and solids content of about 0.1%. The solids can be suspended (about 30%) as well as dissolved (about 70%) (FAO 1992). Dissolved solids can be precipitated by chemical and biological processes; however, the suspended solids can lead to the development of sludge deposits and anaerobic conditions when discharged into the receiving waters.

Chemically, wastewater is composed of organic and inorganic compounds, as well as, various gases. Organic components may consist of carbohydrates, proteins, fats and greases, surfactants, oils, pesticides and phenols. Inorganic components may consist of heavy metals, nitrogen, phosphorus, sulfur, chlorides, toxic compounds, etc., and may have an excessively low or high pH. Gases commonly dissolved in wastewater are hydrogen sulfide, methane, ammonia, oxygen, carbon dioxide and nitrogen (FAO 1992).

Biologically, wastewater contains various microorganisms but the ones that are of most concern to plants and animals are those classified as protista. The category of protista includes bacteria, fungi, protozoa, and algae. Wastewater also contains many pathogenic organisms which generally originate from humans who are infected with disease or who are carriers of a particular disease (FAO 1992).

Human health problems from wastewater

Humans "contract" diseases from wastewater in a variety of ways. Pathogens in wastewater may be transmitted by direct contact with sewage, by eating food or drinking water contaminated with sewage and/ or in which contaminants such as heavy metals may have accumulated. Another important pathogen vector is through contact with other human, animal, or insect carriers. Faeces and urine from both humans and animals carry many disease-causing organisms. Wastewater also may contain harmful chemicals and heavy metals known to cause a variety of environmental and health problems.

Bacteria, viruses, and parasites (including worms and protozoans) found in wastewater are the main types of pathogens that can be directly hazardous to humans. Fungi that cause skin, eye, and respiratory infections and water-borne diseases (i.e. cholera, typhoid, shigella, polio, meningitis, and hepatitis A and E) are also found in sewage and sewage sludge. Animals (including humans) can act as hosts to the bacterial, viral, or protozoal organisms that cause these diseases. (Khan 1997; UN 1997; Warner 1998; WHO 1997). *Escherichia coli* are the most frequent pathogenic agent of urinary tract infections, causing a wide spectrum of clinical syndromes from asymptomatic cystitis to pyelonephritis or sepsis (Sobel and Kaye 1995). Depending on the virulence factors they possess, virulent *E. coli* strains can cause either non-inflammatory diarrhoea (watery diarrhoea) or inflammatory diarrhoea (dysentery with stools usually containing blood, mucus and leukocytes).

E. coli diarrheal disease is contracted orally by ingestion of food or water contaminated with a pathogenic strain shed by an infected person. ETEC diarrhoea occurs in all age groups, but mortality is most common in infants, particularly in the most undernourished or malnourished infants in developing nations (Doyle and Dolores 1997).

Low cadmium exposure level may cause adverse health effects, primarily in the form of kidney damage but possibly also bone effects and fractures. Similar levels of exposure to mercury via food contamination, may increase blood levels and increase the risk of neurological damage to adults and to the unborn foetus of pregnant women (Jarup 2003). Children are also more susceptible to lead exposure due to high gastrointestinal uptake and the permeable blood-brain barrier. Long-term exposure to arsenic in drinking water has been linked to increased risk of skin cancer and some other cancers, as well as other skin lesions such as hyperkeratosis and pigmentation changes. Occupational exposure to arsenic, primarily by inhalation (e.g. of dust resulting from the drying of mid), is causally associated with lung cancer (Jarup, 2003).

Human health problems from consumption and contact with wastewater

In Phnom Penh, about 20% of vegetables consumed are grown in wastewater-fed wetland areas (Muong 2004). Water spinach (*I. aquatica*) is the main crop grown in these wetlands, the Boeng Cheung Ek lake area being the largest. To sustain wastewater use in such peri-urban aquatic food production systems, adverse health implications should be addressed and alleviated. Health risks of wastewater use in agriculture and aquaculture have been reported in many countries like Morocco, Mexico and Pakistan, where wastewater is commonly used for irrigation (Shuval *et al*. 1989; Habbari *et al*. 1999; Cifuentes *et al*. 2000; Blumenthal *et al*. 2001). Outbreaks of cholera, typhoid and shigellosis have been associated with the use of untreated wastewater to irrigate vegetables (WHO 2006). As wastewater-irrigated vegetables passively accumulate faecal contaminants on their surfaces, they may pose a health risk to consumers when the produce is cooked or eaten raw. Increased risk of diarrhoeal disease is associated with the consumption of uncooked vegetables irrigated with wastewater (Blumenthal *et al*. 2003). Water spinach is highly contaminated with faecal pathogens, with more than half the plants being contaminated with Giardia and some plants with *Cryptosporidium spp*. and *Cyclospora spp*. (Anh *et al*. 2007). These findings are the first report from Cambodia on protozoan parasites in vegetables. Pathogens may also be taken up by plant roots and be incorporated into the plant tissue (Guo *et al*. 2002; Solomon *et al*. 2002). Recent results of a study of Cheung Ek Lake on skin diseases suggest that exposure to wastewater is an important risk factor for skin diseases, especially dermatitis (eczema) of the hands and legs (Dalsgaard *et al*. 2005).

Human health problems from crop cultivation

The application of fertilizers and chemical pesticides to Cheung Ek Lake may impact negatively on human health. Increasingly, agricultural chemicals, fertilizers, pesticides, and industrial wastes (including heavy metals) are being found in freshwater supplies. Such chemicals, even in low concentrations, can build up over time and, eventually, can cause chronic diseases such as cancers among people who use the water (Silfverberg 1994).

Health problems from nitrates in water sources are becoming a serious problem; in more than 150 countries nitrates from fertilizers have seeped into water wells, fouling the drinking water (Maywald *et al*. 1998) causing blood disorders (i.e. from excessive concentrations of nitrates) (Bowman 1994). Consistently elevated levels of nitrates and phosphates in water encourage growth of blue-green algae, leading to deoxygenation (eutrophication). Pesticides such as DDT and heptachlor, which are used in agriculture, often contaminate irrigation water. Their presence in water and food products has alarming implications for human health because they are known to cause cancer and neurological diseases and reduce sperm counts (Bowman 1994).

The results from a survey by Teang (2009), water spinach and water mimosa producers in Cheung Ek

Lake apply chemical fertilizers and chemical pesticides on a weekly basis to fight against diseases and insects. The commonly used chemicals and pesticides are:

- DDVP-50 from Thailand (called "Holding-Hand Brand" by farmers) used for prevention of worms and white rust lesions (Kra) (Active Ingredients: 2, 2-dichlorovinyl dimethyl phosphate 50%W/V EC).
- Visher 25 ND from Viet Nam (called "One-Worm Logo" by farmers) used for prevention of worms, grasshoppers and white rust lesions.
- V 80 (known as "Carrying-Pumpkin Brand") from Thailand, used for prevention of white rust lesions (Kra) and conditioning plant bud (Active Ingredients: Zinc ethylenebis (dithiocarbanate) (polymeric) 80% W.P).
- BIOBIT 32B FC from Viet Nam ("One Worm Logo" powder) used as pesticide and for bud conditioning.
- Bao 30 from Thailand (called "Golden Comb Brand" by farmers) used to stimulate new growth of buds.

Based on the results of the survey by the author in 2010, working in the lake without protective gloves and bathing in the lake were the two common reasons resulting in skin problems for the farmers. More fisherman, water-mimosa, and water-spinach cultivators than rice cultivators and duck raisers reported skin problems because they spent longer lengths of time on the lake. Most of the water spinach and water mimosa cultivators realized that their health had worsened because of contact with wastewater chemicals. Furthermore, the fishermen perceived that they had difficulty in breathing, as they had spent an average of 10 hours a day on the lake for fishing activities. The suspected diseases which are mostly encountered by the farmers working in Cheung Ek Lake during the survey are: cough, cholera, typhoid and diarrhoea, which are mostly diseases associated with wastewater. Another case study on Cheung Ek lake by Dalsgaard et al. (2005) also mentioned that the exposure to wastewater is an important risk factor for skin diseases, especially dermatitis (eczema) of the hands and legs.

Human health problems arising from accumulated heavy metals

The contamination of aquatic ecosystems by heavy metals has gained increasing attention in recent decades. Heavy metals represent a significant ecological and public health concern due to their toxicity and ability to accumulate in plants and animals (Alloway and Ayres 1993 and Langston 1998). In natural environments, there exist background levels of heavy metal components in soil and water. However in contaminated areas, plants and animals may begin to accumulate heavy metals. When impacted plants and animals are subsequently used for human food, heavy metal contaminants are often incorporated into the food chain. Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues. Toxic levels of heavy metals have a negative effect on the quality of cultivated plants and animals and later on health of local inhabitants. Heavy metals may enter the human body through food, water, air, or absorption through the skin.

A common heavy-metal contaminant is mercury, which can be used in various industrial processes, as well as being emitted from coal-fired power plants. This metal has a significant vapour pressure under ambient conditions, and thus, apart from mainly infiltrating the human body through food and water, it may also enter through respiration. Moreover, in contact with various organisms, it readily forms compounds such as dimethyl mercury, an highly toxic form, easily passed through the food chain to humans [e.g. the disaster at Minamata Bay, Japan reported by Lui David (1999)]. Mercury is particularly potent because once in the body it cannot be excreted but accumulates in the body tissue and, significantly, in mother's milk (Lui David 1999).

Together with respiration, food can be considered as the greatest vector for toxic chemicals to the human body. Local inhabitants of Cheung Ek Lake consume local fish and sell farm produce which is collected from the contaminated lake. The increased concentrations of metals in fish, such as mercury, lead and cadmium, may pose a threat to human health through consumption (Chen and Chen 1999), although some metals (zinc and copper) are essential trace minerals for metabolic regulation at cellular and tissue levels (Vallee and Faclchul 1993). Aquatic plants often accumulate metals from their environment (Outridge and Noller 1991; Ali and Soltan 1999). Fish is the most common meal for the people living around Cheung Ek Lake. Thus, humans can be affected by bio-accumulation process of heavy metal through the plant/fish life. Chronic exposure to and accumulation of heavy metal by aquatic biota can result in tissue concentrations that will have adverse effects on exposed organisms (Bolognesi *et al.* 1999).

For the general Cambodian population, any effects from accumulated heavy metals caused by untreated industrial effluent impacting Cheung Ek Lake will be widespread as a consequence of the market distribution of water spinach being sold to three main markets in Phnom Penh and transported to other provinces throughout Cambodia. The accumulated heavy metals could result in serious chronic illnesses such as cancer, and neurological diseases as well as an increase in birth defects. In Karachi, Pakistan, for example, a study found that poor people living in areas without any water treatment plants spent six times more on medical care than people who had lived in areas with access to appropriate sanitation and who had a basic knowledge of household hygiene (Khan 1997).

Long-term effects of doing nothing or draining the lake

Doing nothing about pollution problems, and the continuous urban and industrial activity draining into the lake will result in the deterioration of the regional economy and the health of people living around and eating products from the lake. Negative effects of lake water pollution result from untreated wastewater draining into the lake and the direct application of the fertilizers and chemical pesticides on the lake for water spinach and water mimosa cultivation. The raw wastewater will lead to many kinds of widespread water-borne diseases among the population. Moreover, the toxic substances from agricultural and industrial waste practices will build up over time through bio-accumulation process and may cause chronic diseases such as cancer, birth defects and blood disorders. These kinds of diseases require expensive and continuing medical treatment and if a significant fraction of the population suffers from them, this will have a deleterious effect on the national budget, not the least of which arises from lack of productivity of the diseased or ill population. Furthermore, the negative cost factors of effectively doing nothing about pollution of the lake will result in the removal of residents, no land development around the lake, loss of current and future industry such as fishing and cropping practices, tourism and recreation. The loss of future tourist income would be considerable: for example, Ho Tay Lake in Hanoi is a major tourist attraction, adding greatly to the beauty of the city and hence resulting in considerable earnings from domestic and international travellers. Moreover, it is very important to note the dangers of contaminated sediments from the bottom of the lake being exposed to air. The resulting contaminated dust, heavy metals mostly, will spread contamination much further than is possible by just draining wastewater into the lake. The primary source of air contamination at lake sites is the dust from the dry surfaces of sediments, if they are exposed to the environment. Often, in the dry season sediments in Cheung Ek Lake are not completely covered by water, thus the dusts from dry sediments, heavy metals in particular, are commonly available for wind-blown transport. Deposition of wind-blown tailings provides exposure routes for contamination of ground water, surface water, and soil which is a great concern to public health.

Converting the land reclaimed as a result of draining and filling in the lake to commercial and housing uses will put heavy socio-economic pressure on both the local people who live and work dependent on the lake, and on the Cambodian government. Thousands of poor people who live around the lake will lose their livelihood as producers of aquatic plants, fishermen, dry season rice cultivators and duck producers cease operation. Moreover, there will be a decrease in food production if this lake is filled for urbanisation. As it is already known, the products from Cheung Ek Lake, water spinach and water mimosa in particular, supply not only the consumers in the capital city of Phnom Penh but also to the other main provinces including Sihanouk Ville, Koh Kong and Kampong Cham. If the geographical locality now used for producing this kind of vegetable is converted for modern buildings, how should the displaced people earn their livelihoods? How can we get enough food products reaching the demands of consumers? On the other hand, to where should the waste water be drained? These main critical questions need to be answered before Cheung Ek Lake can be considered as a site for urbanisation.

Proposed solutions for solving negative impacts from lake contamination

Finding solutions for the security of Cheung Ek Lake and its surrounding environments must be a high priority in the short and intermediate terms. If the changes are not implemented quickly serious problems will inherited by future generations. Establishing strict policies and laws relating to municipal and industrial waste practices, crop cultivation on the lake and the building water treatment facilities should be implemented as soon as possible. As a preliminary step, the government should establish strict regulations for water spinach cultivation on the lake. Direct application of fertilizers and chemical pesticides on the lake should be minimised and municipal and industrial waste disposal practices must be closely monitored. The proper disposal of wastewater is crucial to the health of the community. The overriding advantage of proper wastewater disposal is the prevention of the spread of diseases. Human waste products contain bacteria and other micro-organisms that cause serious and costly long term diseases such as typhoid fever and hepatitis. If the disposal of wastewater containing disease-causing micro-organisms continues to be unregulated, deadly diseases have the potential of being transmitted throughout the local community. Another benefit of proper wastewater disposal is the protection of the lake from pollution, which can negatively affect fish populations and can promote the growth of weeds and algae destroying the productivity of the lake. In the long-term, industrial wastewater should be treated separately from domestic wastewater, by enforcing the requirement for each industry to obey discharge limits (maximum levels of heavy metals, etc.), as is done in developed countries.

It is recommended that a wastewater treatment plant should be established to reduce pollutants flowing unchecked into the lake. A basic wastewater treatment plants could treat and remove dangerous, disease causing bacteria and suspended solids before allowing remaining water, called effluent, to be discharged into the environment. By combining strict regulations and with the establishment of a wastewater treatment plant, the Cambodian Government can begin to be effective in reducing problems already occurring in this lake area and work towards an environment that is productive and healthy.

Proposed waste water treatment plant

An effective wastewater treatment plant has three stag-

Table1. Comparison in terms of cost-benefit effectiveness between doing nothing or draining the lake and setting up waste-water treatment plant

Option	Advantage	Disadvantage
Doing nothing/draining the lake	– No cost to set up the plant – Industry does not need to pay the cost to sustain the water treatment plants for their waste – No space needed for the wastewater treatment plant – No infrastructure need be built	– Long-term health effects on local people living in Cheung Ek Lake communities – Unhealthy food products from the lake – The lake will contain more chemical waste and polluted substances – Cost more for local people for medical bills – More wastewater-borne diseases – Need for removal of residents at some stage
Setting up wastewater treatment plant	– Positive health benefits for local community – More healthy food will be produced – Clean water can be re-used for agricultural purposes and more agricultural production activities – The lake can be a tourist attraction site after the water is treated	– Require a large amount of money for the plant – Build infrastructure for the plant set up – Industry in the city will need to pay for draining their waste, and then passing costs on to their customers – Large space is required to set up the plant

es of processing (see Figure 1).

Stage 1: the primary treatment starts with the mechanical agitation (Macerator) without aeration. The waste elements are broken into small pieces which results in faster and more complete breakdown in subsequent biological processes. Organic waste is removed at this stage but not other sorts of pollution such as nutrients or pathogens, leaving a material containing only water-soluble compounds, pathogens, small solid particles and liquid droplets.

Stage 2: a coagulant is added to the treated material from Stage 1; the coagulant, comprising a polymeric flocculant, causes the solid particles to stick together to form an aggregate. The mechanism for this is complex, but the simplest description is that the polymer acts like a long rope which attaches itself to many particles and thus causes these bound particles to collide with and stick to other collections of bound particles. The result is a macroscopic solid which can settle out of suspension or which can be filtered off. The polymers (which are typically added at the parts per million, ppm, level) produce no significant additional solids and reduce waste sludge volume. It can also result in higher-quality water for re-use.

With polymeric flocculants, the effluent produced is essentially free of bacteria and solid pollutants; although the volume of the recovery water will be lower than the inflow volume. An aerator is used to improve formation of the sludge treatment and removal of common pollutants through biological processes. An aerobic process is used to avoid odours and digested sludge coming to the water surface, while floating solids are retained by a scum board in the inlet area. With an aeration process, the effluent produced has significantly better water quality, and the final discharge may contain dissolved oxygen which reduces the immediate oxygen demand on the receiving water. The aerobic environment can also eliminate many pathogens present in agricultural wastes.

Stage 3: settling ponds are used to produce high-quality treated water. The processed water is allowed to stand temporarily in the ponds. The sludge will then sink to the bottom of the ponds and the higher-quality water will be at the surface. Then, the recovery water is drained back into the lake with a much higher quali-

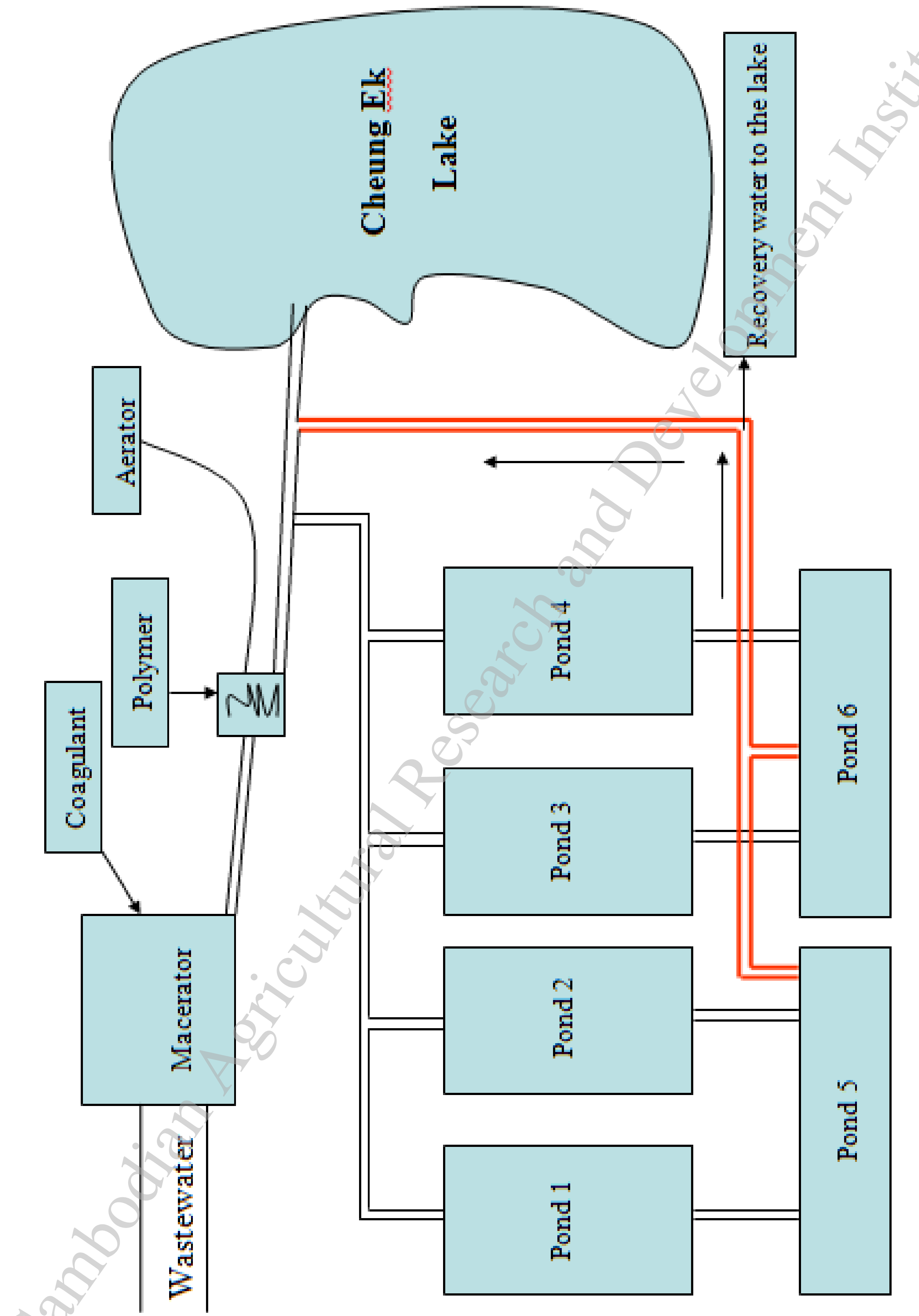

Figure 2. Proposed model of water treatment plants for Cheung Ek Lake region.

ty. Although this whole process requires significant nation-building investment, including the specialists needed to set up the treatment system and the settling ponds, the benefits for sustainable waste management will be enormous.

Positive impact of wastewater treatment

The economic question then becomes the quantification of the cost of:

1. Setting up a water treatment/purification process (high short-term costs) and running this over the years (relatively small intermediate- and long-term costs),
2. Doing nothing (no short-term costs, extremely high intermediate- and long-term costs),
3. Draining the lake and using the land for commercial and housing purposes, which will have short-term profit and enormous intermediate and long-term costs.

An appropriate treatment plants need to be implemented because it is the most effective solution to treat the wastewater from both commercial and domestic waste. Initially, if there is a high cost investment to set up this kind of system for just a single lake. However, it is very cost effective if it is offset against the negative impacts on public and environmental health from doing nothing. This enormous expense from negative cost factors will put more pressure on the government and also on the households who live and work on the lake and the people who consume the products from the lake. If the pollution continues, remediation of these problems will require a longer clean-up period and huge expense. Thus, operations on wastewater treatment should be implemented immediately so the situation is still at a stage where it can be solved with relatively small negative impacts. While the cost of building water treatment plants is high, the costs of *not* doing so can become staggering.

Conclusions

Cheung Ek Lake is a vital economic resource on the urban margin of Phnom Penh. For the about 500 families directly living on the lake it is their home and represents their livelihood. The agricultural activities provide a vital fresh food source for markets in Phnom Penh and surrounding economic hubs. This rural economy also involves growers, wholesalers, distributors and local customers, and provides a valuable trade network in essential commodities such as foodstuffs and animal fodder. However, if the large peri-urban water body of Cheung Ek Lake is to remain viable, a rapid response to the problem of wastewater must be initiated. The considerable volumes of untreated industrial and municipal waste water that currently flow into the lake will, in time, cause irreversible contamination of this resource. Contaminates, such as heavy metals and organic wastes from industrial sources, disease-causing agents from untreated human and animal wastes and excess nutrients, can cause chronic and debilitating health issues in the population around the lake. Although the first signs of health problems are likely to appear in the local community, with an established trade in contaminated goods and population movement, the illness and disease will spread more widely. This constitutes a massive future medical bill for the Cambodian Government compounded by rising employment difficulties when people are unable to work or take sick leave.

To reverse this bleak picture a relatively simple process of wastewater treatment should be implemented as soon as possible. Treating municipal and industrial waste at the most basic level is the first step. This basic plant can then be extended and expanded until waste water is being treated to a high quality. Swift implementation of this proposal, coupled with more strict regulations on industries and municipal groups that produce waste as well as controlling farming practices on the lake, will allow Cheung Ek Lake to regain its place in the economics of this region and vastly improve the health and well being of people who live and work there.

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