揭開基隆河的水質祕密

To uncover the secret of the water quality of Keelung River

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摘要

基隆河位於明倫高中旁邊，觀察發現河水流向偶而會有逆流而上的現象，屬於感潮河段。我們將透過河川水位變化探討感潮河段的分布範圍，並利用自製的抽水馬達取得不同深度的水，透過實際調查了解大龍抽水站出水口的水質狀況，包含鹽度、濁度、河川抗酸能力…等。

ABSTRACT

Keelung River is located next to Minglun High School. Our observation shows that the flow of water occasionally has a counter-current phenomenon, which belongs to the tidal river. We will explore the distribution of tidal reach through the change of river water level, and use self-made pumping motor to obtain water from different depths. Through actual investigation, we will understand the water quality of the outlet of Dalong pumping station, including salinity, turbidity, river acid resistance ... and so on.

研究問題

（一）　確認感潮河段的分布範圍
（二）　檢測半天內，測站每小時的水質變化情形
（三）　檢測一小時內，測站水質隨深度變化情形
（四）　檢測降雨後，鹼度隨時間變化情形

Research Questions

I. Confirmation of the range of the tidal river
II. Detection of how water change at station per hour half a day
III. Detection of variation of salinity of water with depth within an hour
IV. Detection of variation of alkalinity over time after rain

環境介紹

我們選用學校旁邊的大龍抽水站，大龍抽水站位於台北市通河西街一段 2 號，主要是處理承德橋至百齡橋這個區段的雨水，大隆抽水站位於基隆河左岸，屬於凹岸地形，且有小橋橫跨出水口，因此取水時相對於河岸更方便安全外，也可以了解人類活動對水質的影響。

Enviroment Introduction

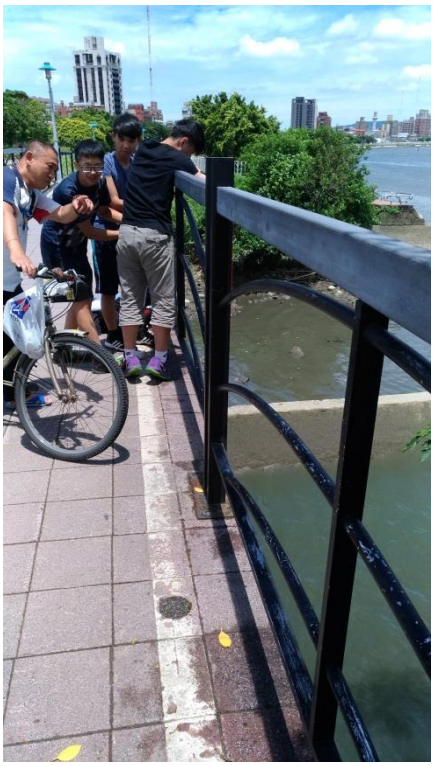
We choose the Dalong pumping station as our researching subject. The Dalong Pumping Station is located at No.2, Sec. 1, Tonghe W. St., Datong Dist., Taipei City, next to our school. It handles mainly the rainwater from this section of Chengde Bridge to Bailing Bridge. The Dalong Pumping Station is located on the left bank of Keelung River, Shore terrain, and a small bridge across the outlet. Therefore, it would be more convenient and safe for us to take water, compared with taking it from the river bank; besides, we can also understand the human impact on water quality.

圖一 大龍抽水站位置圖，圖中星號為取水測量地點

Figure 1：Dalong pumping station location map, asterisk meaning the water measurement site

圖二 選擇安全的測量地點

Figure 2 : Choosing a safe place for measurement



圖三 路人經過時，關心我們的測量狀況，並說明過去的河水狀況

Figure 3 : One passers-by was concerned about our measurements and explained the state of the river in the past

● 水質調查項目

（一）濁度

當工業廢水或都市廢水排進河川時，水中有機物和無機物可能飆高，而水中細菌和微生物會附著在這些物質上；若是農業廢水排入則會造成氮、磷等含量超出正常範圍，造成水質優養化使藻類大量繁殖，濁度亦會上升。我們使用濁度管來測量河川濁度，濁度管是一個透明圓形塑膠管，底層顏色是由黑白相間的各兩個四分之一圓，操作時要背光以減少陽光影響，由一個人將取到的河水注入，直到看不見底下的黑白交界，然後記錄當時水位高度；再將剩餘的水倒入，最後由濁度管下方的放水孔將水放掉，直到再次看到底下的黑白界線時記錄數值，取兩者的平均值代表河川的可透視度。我們利用濁度管的可透視度去評估河水濁度，可透視的深度越深，代表河水越清澈。

● Water quality Investigation project

I. Turbidity:

When industrial wastewater or municipal wastewater is discharged into the river, the organic and inorganic matter in the water may soar. Bacteria and

microorganisms in water will attach to these substances. If agricultural wastewater replace the former wastewater, nitrogen and phosphorous will go beyond the normal level, resulting in high quality of algae breeding and high turbidity. We use a turbidity tube, a transparent circular plastic tube, to measure the river turbidity. The color of its bottom consists of two quarter-circles of black and white. The backlight is operated to reduce the influence of sunlight; one researcher instills water we had taken into turbidity tube until we could not see the bottom of the black and white junction and then recorded the water level. Then he pours the remaining water, emits the water from the drain hole below the turbidity tube until we see the recorded numbers on the bottom of the black and white boundaries again .We take the average of the two numbers to represent the transparency of the river—the deeper of the transparency of the river means the river is clearer.

（二）鹽度

鹽度是指每一千公克水中所含溶解物質的克數。測量時比重計放入待測水溶液中並觀察當時比重計在水面的高度來測得當時的浮力，並對照當時溫度查表得到當時鹽度的值。

II. Salinity

Salinity refers to the grams of dissolved matter contained in each kilogram of water. When measuring, we place the hydrometer in the aqueous solution under test and observe the height of the hydrometer at the time to measure the buoyancy, and then check the current salinity to obtain the salinity value at that time according to the temperature.

（三）鹼度

鹼度是指水中能夠與強酸進行中和反應的物質含量，河水中的鹼度主要來自於地表沖刷的碳酸鹽、重碳酸鹽及氫氧化物的濃度，可以用來表示河川抗雨水酸度的能力。一般而言若是河水的酸鹼度日變化幅度越大，越不利於生物生存，造成大規模的死亡。因此河川的鹼度夠大時，酸雨無法立即的改變河水的酸鹼值，能維持水中生態平衡。一般河川鹼度在 50ppm 以上，代表生態系統可以比較穩定，小於 200ppm 時會抑制生物生長。

III. Alkalinity

Alkalinity refers to the materials in the water which can neutralize strong acid. River alkalinity, mainly from the concentration of carbonate salt, bicarbonate and hydroxide, resulting from the erosion of surface, can indicate the ability to resist acidity of a river. Generally speaking, the wider the daily changing scope of pH values in the river is, the worse the living

environment for creatures becomes, which may lead to large-scale death. As a result, alkalinity maintains the ecological balance of river water as long as the alkalinity of the river is so large that acid rain can not immediately change the pH of the river. The common alkalinity in the river is above 50ppm, representing a more stable ecosystem, while alkalinity below 200ppm will inhibit biological growth.

- 取水方法的改變

一開始，我們用桶子綁上繩子，丟到河裡取水(圖四)，但是只能撈到表層的水；後來我們改用沐浴乳壓頭搭配 4 公尺的水管(圖五)，並在下方繫上重物，使水管不受浮力或水流影響，進而得到不同深度的河水。這次我們研究中最特別的是，為了能在短時間之內快速取得不同深度的河水，我們自行改裝小型抽水馬達(圖六)，並利用量尺測量，由表層往深處每 20 公分取水一次。

- **The Change in the Methods of Obtaining Water**

We tied the rope with the bucket at the beginning, and then throw it into the river to take the water (Figure 4), but we could only get the water from the surface. Hence, we use the shower head with a 4-meter water pipe (Figure 5), and tied the weight below, which allows us to obtain water without the pipes being affected by buoyancy or water flow. The most special point about our study is that in order to quickly obtain river water from different depths in a short period of time, we self-adapted a small water pumping motor and measured it with a dipstick (Figure 6), taking water every 20 cm deep from the surface.

圖四 水桶取水

Figure 4 : Taking water with the bucket

圖五 壓頭式

Figure 5 : Indenter

圖六 自製電動抽水馬達

Figure 6 : Self-made electric pumping motor

- 研究成果

感潮河川的水位、鹽度有可能會隨著海水含量高低而有數據上的差異，滿潮時水位能漲到最高點，此時海水極有可能進入至內陸區域，影響河川的鹽度 、溶氧量導電… 等，因此我們連續觀測數次 ，希望能找出海水與河川質的關聯性並探討其數值變化的。

- **Results**

The water level and salinity of the tidal river are likely to vary with the sea water mixing with the river. At the time of full tide, with the water level reaching the highest point, the sea water is most likely to enter the inland area, affecting the salinity of the river and the amount of dissolved oxygen conductive. That's why we continuously observed several times, hoping to find out the relevance of sea water and river quality as well as to explore the numerical changes

（一）確認感潮河段的分布範圍

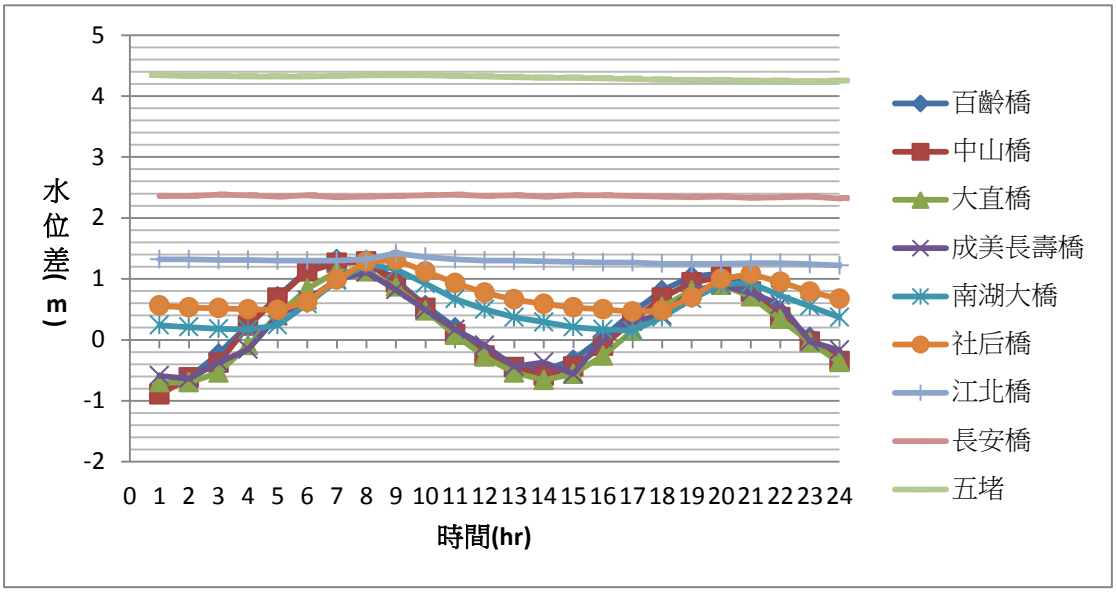
觀察 2017 年 5 月 20 日基隆河水位站的逐時水位資料圖(圖八)，發現社后橋之下的水位站水位變化與潮汐週期很類似，每隔 12 小時左右一個循環。百齡橋到長壽橋之間的水位變化很相似，但是此一區段的水位高低與水位站的上下游位置沒有絕對相關；南湖橋到社后橋的曲線變化變得比較平緩一些；到了江北橋站之後水位就沒有明顯的變化，甚至到了五堵站，幾乎像是一條接近平坦的直線，故推測當日潮汐能影響範圍到社后橋（標高 160 公尺）便結束。

I. Confirmation of the distribution of tidal reach

Observing the hourly water level data chart of the Keelung River Water Station on May 20, 2017 (Figure 8), we found that the water level change at the water level under Shehou Bridge is very similar to that of the tidal cycle, with a cycle of about 12 hours. The change of water level between Bailing Bridge and Zhongshou Bridge is very similar, but the water level in this section is not absolutely related to the upstream and downstream position of water level station. The curve change of Nanhu Bridge to Shehou Bridge becomes more moderate. There was no obvious change in the water level after the Jiangbei station, and even to the Wudu stations, almost like a straight line close to the flat, it is speculated that the tidal range of the day the impact of the community to Shehou Bridge (elevation 160 meters) is over.

圖七 經濟部水利署基隆河水位站分布圖

Figure 7 : Ministry of Economic Affairs Water Resources Department Keelung River water level distribution map



圖八 2017 年 5 月 20 日經濟部水利署基隆河水位站逐時水位資料圖

Figure 8 : Hourly water level data chart of Keelung River Water Station, Ministry of Economic Affairs, Ministry of Economic Affairs, May 20,

（二）檢測半天內，測站每小時的水質變化情形

(圖九)是 2017 年 5 月 20 日（農曆 4 月 25 日）8 點~19 點在大龍抽水站出水口，每一小時河水的水質調查數據，圖的上半部是鹽度及濁度管的可透視度的逐時變化，圖的下半部是抽水站水位的高度資料。我們發現退潮時（8 點~13 點），水質逐漸清澈（透視度提高），鹽度沒有明顯的變化趨勢；漲潮時（14 點~19 點），鹽度與可透視度也會跟著上升。

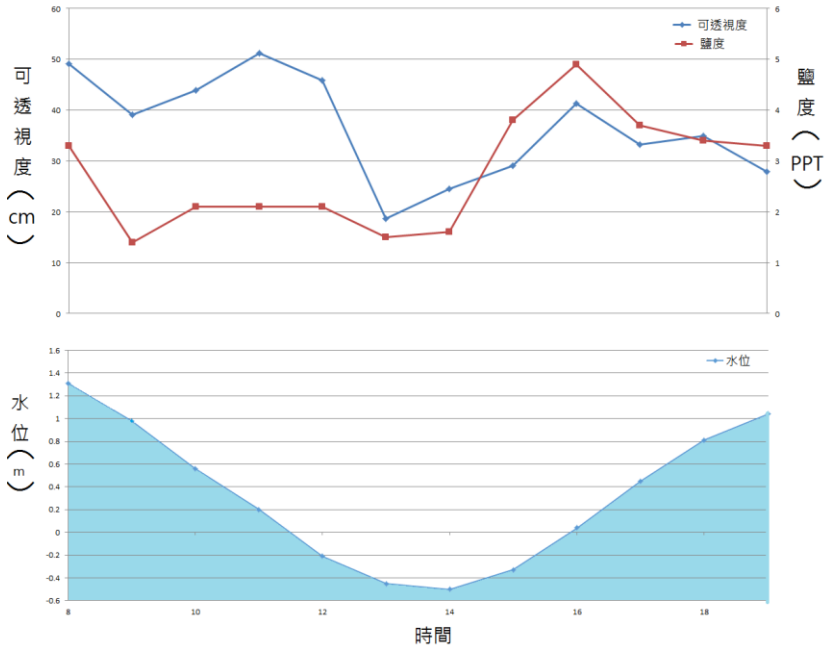
根據海洋環境學—談台灣沿海環境（范，2006），受到河水和海洋交互影響，河川出海口的河口部份分為三種類型，鹽楔型、混合型和部分混合型。數據顯示在滿潮（8 點）與乾潮（14 點）前後，數據上下跳動沒有一致性，我們推測可能因為此時正好是海水流速轉變，與向下游流動的河水作用而產生紊流，造成河川的濁度提高（可透視度降低）、鹽度的變化沒有規律性。

II. Measuring the hourly water quality changes in the station in half a day

(Figure 9) May 20, 2017 (Lunar New Year April 25) 8:00 ~ 19:00 *Water quality survey data for each hour at the Dalong pumping station outlet*

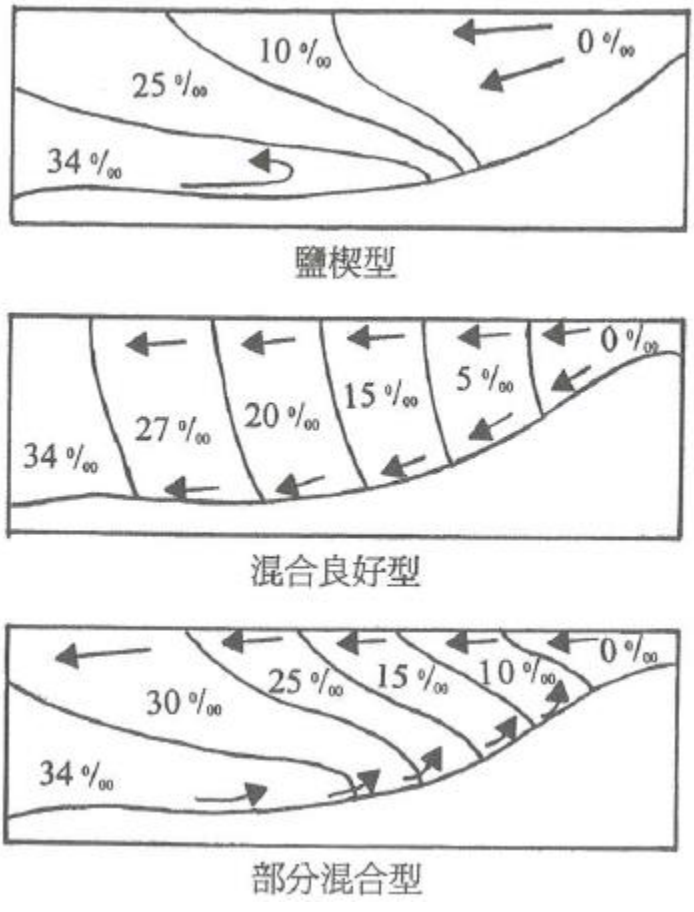
The top half of the figure is changes in the salinity and turbidity degree of tube visibility from time to time, while the lower part of the figure is the information about height of the pumping station water level. We found that at low tide (8 o'clock to 13 o'clock), the water quality gradually became clear (the degree of transparency increased) and the salinity had no obvious change. During the high tide (14 o'clock to 19 o'clock), the salinity and the degree of transparency would also increase.

According to *Marine Environment - Talking about the Coastal Environment in Taiwan (Fan, 2006)*, influenced by the interaction between rivers and the sea, the estuaries to the sea are divided into three types, salt wedge, mixed type and partial mixed type. The data shows that there is no consistency in the up-and-down data before and after the full tide (8 o'clock) and the dry tide (14 o'clock), and we assume that the turbulence caused by the change of seawater velocity interacting with seawater flow at the downstream may lead to the rise of turbidity (the lower degree of transparency) and the irregularity of the salinity changes.



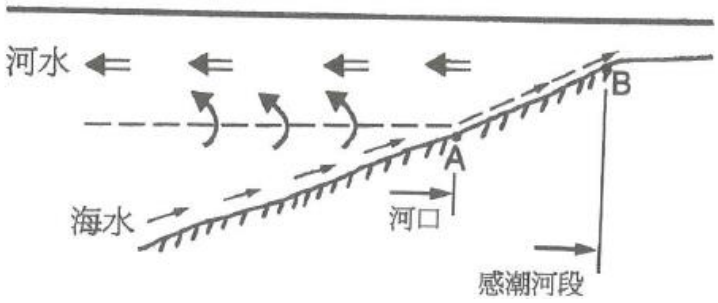
圖九 水位、鹽度與可透視度折線圖

Figure 9 : water level, salinity and transparency line chart



圖十 一般河口的三種類型

Figure 10 : Three types of general estuary



圖十一 河口垂直環流的特徵

Figure 11 : Characteristics of estuarine vertical circulation

圖十二 圖紊流示意圖

Figure 12 : turbulence schematic

（三）檢測一小時內，站河水鹽度隨深變化情形

我們在 2017 年 8 月 21 日中午 11 點到 12 點進行不同深度的鹽度測量，每 20 公分取一次水，直到深度 340 公分的地方。根據測量結果顯示，測站的河水鹽度會隨著深度產生變化（圖十三），表層河水的鹽度為千分之 5.17 鹽度隨深的變化率約為 0.0195 ppt/cm，趨勢線的公式為

X（鹽度）= 0.0195Y（深度）+5.1708

R2（決定係數）= 0.8588

我們測量出來的數值與趨勢線的預測值之決定係數高達 0.86，顯示趨勢線對鹽度隨深度的變化情形有很高預測能力。

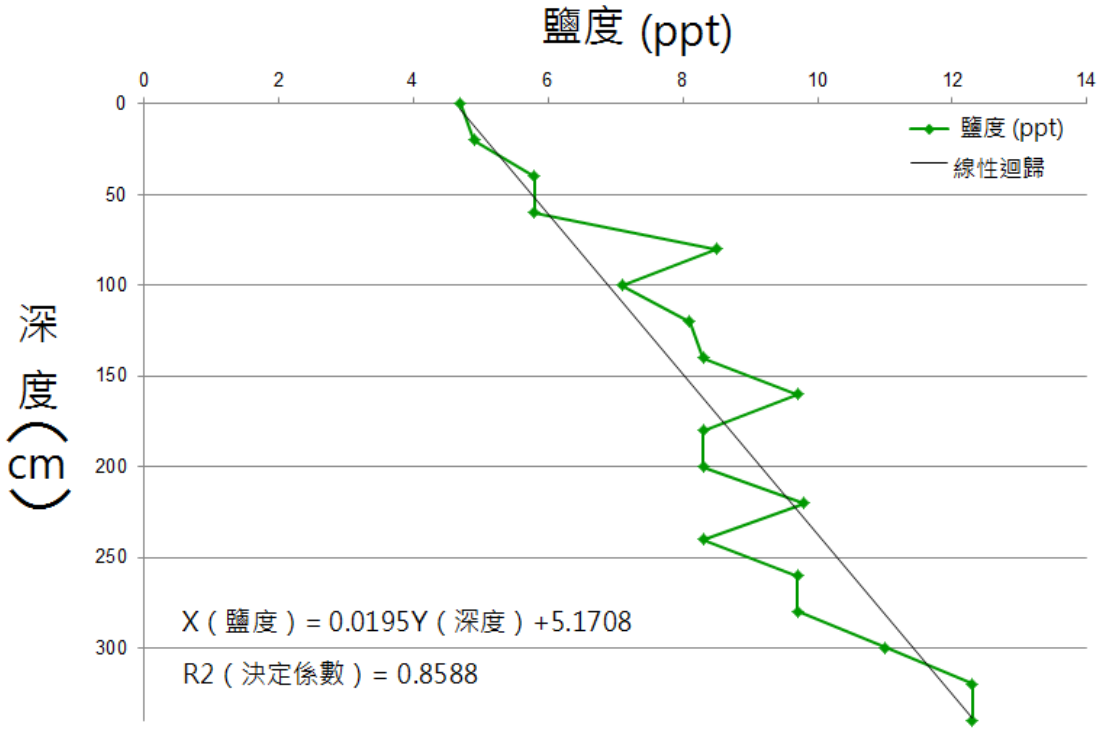
III. Detecting Salinity of the Station River Changes with Depth within one hour.

We conducted salinity measurements of different depths between 11:00 and 12:00 on August 21, 2017, taking water every 20 cm from the surface to a depth of 340 cm. According to the results from measurement, the salinity of the river will change with the height of the station (Figure 13). The surface water salinity is 5.17 thousandth, and the rate of change in salinity with depth is about 0.0195 ppt/cm. The formula for the trend line is

X（salinity）= 0.0195Y（depth）+5.1708

R^2（decisive factor） = 0.8588

The coefficient of determination of the value we measured and the predicted value of the trend line is as high as 0.86, indicating that the trend line has a high predictive power for the salinity variation with depth.



圖十三 河水鹽度隨深度變化圖

Figure 13 : The variation of salinity with depth

（四）檢測降雨後，鹼度隨時間變化情形

(圖十四)是降雨量、河水 pH 與鹼度變化圖，橫軸為時間，從 2017 年 10 月 11 日中午 12 點半開始累計時間，單位為小時。圖中下方是明倫高中氣象站的雨量，圖中上方的紅點為當日雨水的 pH 值，藍色折線為測站測得的鹼度。

觀測發現，即使連日降下豪雨，台北的雨水依然很酸，介於 3.8~4.6 之間，仍低於環保署對酸雨的定義（pH5）。10 月 11 日之前，有幾日沒有下雨，測站的河水鹼度約為 70~80ppm，一旦下雨，鹼度就會下降，但是鹼度最低到 24ppm 就不再下降，當雨量減少時，鹼度就會略微回升。根據前人研究，河川鹼度大約要 200ppm 才比較能夠抵抗酸雨造成的河川生態危機，可是測站附近卻低於 70ppm，不曉得這是否和我們常見的死魚漂浮在水上有關？

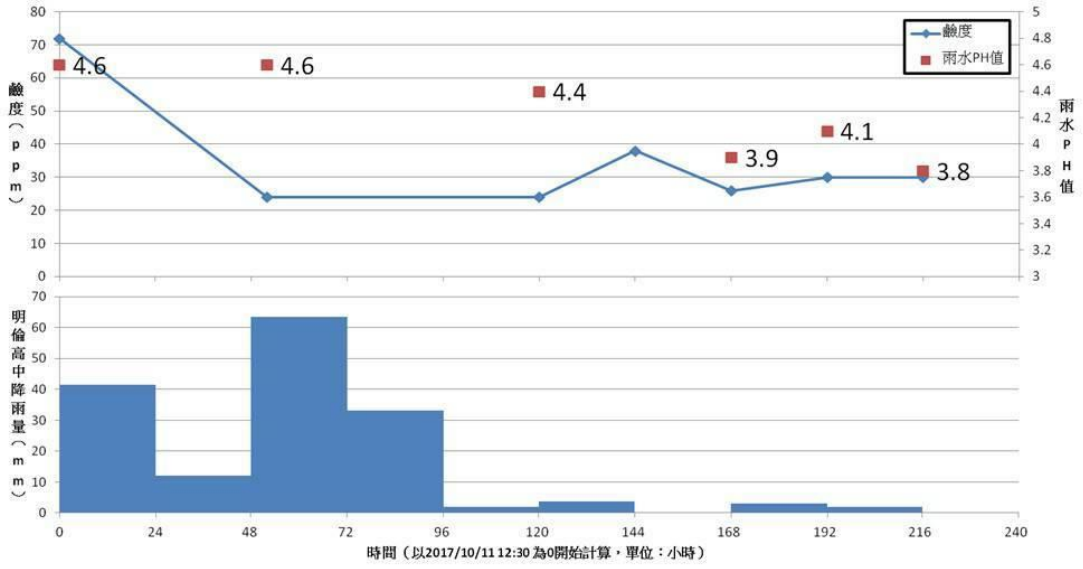
雖然礙於研究時間長度的不足，我們無法統計出鹼度隨時間的恢復能力，但是卻發現一個新的有趣議題：為什麼鹼度降到 24ppm 就無法再降低呢？是因為多日下雨雨水不那麼酸了嗎？但是觀察酸雨的 pH 值，卻依然很低！還是河水中含有甚麼物質，可以忽略酸雨的影響呢？這些期待未來能找到新的證據說明！

IV. Alkalinity changes with time after the detection of rainfall

(Figure 14) is the rainfall, river pH and alkalinity changes. The horizontal axis is the time, having been accumulated every one hour since 12:30 on October 11, 2017. The lower part of the figure shows the rainfall of the Minglun High School weather station. The red point at the top of the figure shows the pH value of the rainwater that day and the blue polyline shows the alkalinity measured by the station.

Observations show that the rain in Taipei is still souring between 3.8 and 4.6, even though the rainfall has fallen for days, still below the EPA's definition of acid rain (pH5). A few days before October 11, there was no rain. The river's alkalinity at the station was about 70-80ppm. Once it rained, the alkalinity decreased. However, when the alkalinity dropped to as low level as 24ppm, the rainfall dropped and alkalinity would rise slightly. According to previous studies, about 200ppm of river alkalinity is more resistant to the ecological crisis of rivers caused by acid rain, but lower than 70ppm of river alkalinity near the station is not. We are not sure whether that is closely-related to a common phenomenon—dead fish floating on the water?

Although we could not figure out the recovering ability of alkalinity over time due to the shortage of research time, we found a new and interesting topic: Why can’t alkalinity reduce below 24 ppm? Is it because the rain is not so acid owing to a longer period of rainfall? However, the pH value in acid rain observed by us is still very low! Or may some materials in the river water weaken the impact of acid rain? All these problems are expected to be solved with new evidence in the future!



圖十四 降雨量、河水 pH 與鹼度變化圖

Figure 14 : rainfall, river pH and alkalinity changes

結論

1. 基隆河的感潮段從百齡橋、中山橋一直延續到社后橋，水位變化週期約為 12 小時，潮差最大的地方在中山橋和大直橋，從江北橋之上的河段已無明顯潮汐變化，推測當日潮汐能影響範圍到社后橋（標高 160 公尺）便結束。
2. 表層河水的鹽度為千分之 5.17，鹽度會隨測站的河水深而增加，垂直遞增率為 0.0195 ppt/cm，證明海水有入侵到大龍抽站，基隆河屬於感潮河川，且海水主要在底層流動。
3. 測站的鹽度和可透視度在漲潮初期會隨水位增加，但是在滿潮與乾潮前後，可能會因為紊流擾亂河水與海的分層現象，導致數據變化沒有規律性。
4. 觀測期間，量到的雨水皆為酸雨，pH 值介於 3.8~ 4.6 之間。未下雨時，河水的鹼度約為 70~80 ppm 一旦下雨，鹼度就會下降，但是鹼度最低到 24 ppm 就不下降，顯示河川有最基本的抗酸能力。

Conclusions

1. The tidal reach of Keelung River starts from Bailing Bridge, Zhongshan Bridge to Shehou Bridge, and the period of tide is about 12 hours. The largest tidal range is in Zhongshan Bridge and Dazhi Bridge, there is no obvious changes in Jiangbei Bridge. Based on the data collected on that day, we presume the influences of tides end at Shehou Bridge (elevation 160 meters).
2. The salinity of surface water is 5.17 per thousand. The salinity will increase with depth, and the variation of vertical rate is 0.0195 ppt / cm. It’s proved that the sea has reached the Dalong pumping station, and the sea water flows in the bottom of river. Keelung River is indeed a tidal river.
3. The salinity and visibility of the water samples will increase with the start of the flood tide. However, between the changes of high tide and low tide, the data is irregular. That might be caused by the turbulence that disturbs the stratification of the river and the seawater.
4. The rain are all acid rain and the pH value is between 3.8 ~ 4.6 during the observation period. The river's alkalinity is about 70-80 ppm when it is not raining. Once it rains, alkalinity will drop, but it won’t decline as low as 24 ppm. Indicating that the river has the basic acid resistance.

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