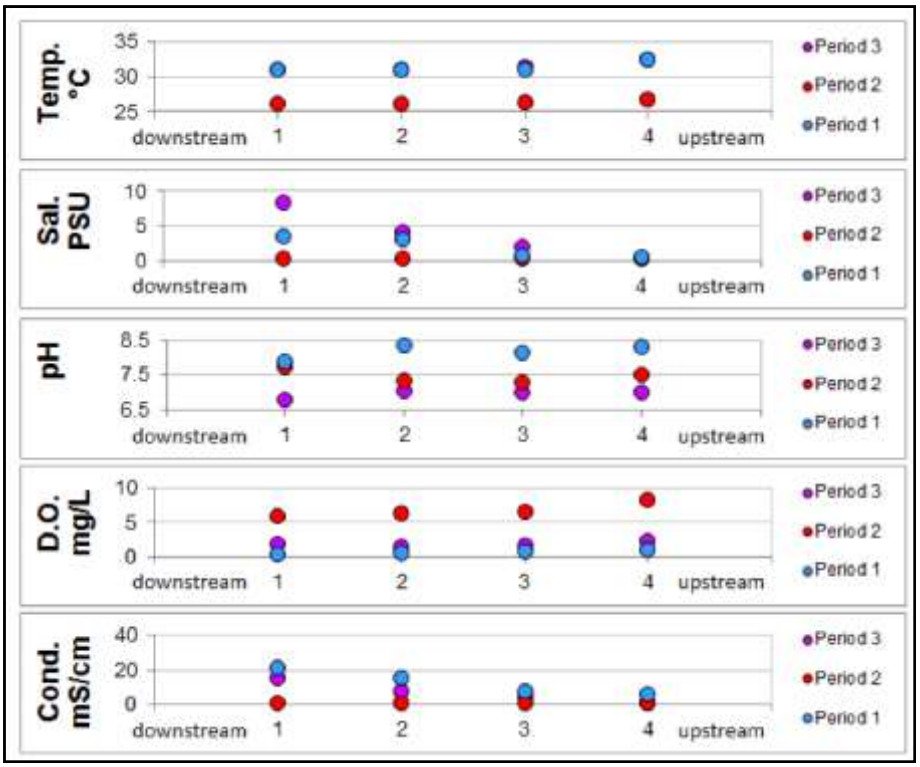

Fig. 3 Physico-chemical parameters

Conductivity, on the average, followed the trend of the water temperature as Period 1 (13 ± 0.46 mS/cm) is the highest, followed by Period 3 (7.23 ±0.76 mS /cm) and Period 2 (0.83 ± 0.01 mS /cm) as the least. Water conductivity gives an idea of the ionic content of the aqueous solution [14].

In terms of salinity, for Period 1 only half of the Pasig River stretch reached the saline water (mouth of the Manila Bay until the intersection near San Juan River). Pasig River has no influence of salinity during Period 2. Period 3, highest level of salinity, was brackish, salinity reached Site 3 while the site near the Laguna Lake remained in the freshwater level. High salinity can induce slight increase in Ibuprofen adsorption [15]. [16], however, showed that the increase in salinity has an indirect effect on Ibuprofen. According to this study, high salinity induced potential release of increase of microbial population. This can be a plausible condition (limiting the adsorption rate) on why Period 3 has higher detected Ibuprofen concentration than Period 1.

For pH, in between Period 1 and 3, Period 1 being alkaline/basic while Period 3 is acidic. From here, it can be observed that Ibuprofen sorption favors acidic environment. This is the hydrophobic repulsion (main contribution of adsorption) decreases as pH increases [17], [18].

Opposite tendency was observed for the average dissolved oxygen (DO) as Period 2 as the highest in acceptable level of more than 5mg/L (6.7 ± 0.13 mg/L), followed by Period 3 which is in hypoxia (1.8 ± 0.15 mg/L). Period 1 is the least, experiencing close to the level of anoxia (0.72 ± 0.33 mg/L). DO presents an overview of the aquatic life in the natural aqueous solution [19]. Low DO level can induce production of microorganisms feeding in the aqueous system. Hypoxia favors phytoplankton blooms, while, anoxia can cause environmental stresses due to bacterial formation. A study showed that if Ibuprofen is at low level, the presence of a diatom *Navicula sp.* could hinder the degradation of this pharmaceutical drug [20]. Thus, prolonging its stress on the aquatic system.

It is also interesting to look at the sources and supply of this pharmaceutical drug, yet as this river is an open reservoir, with uncontrolled waste dumping and water

treatment plants and proper sewerage system lacking, uncertainty is high. Nonetheless, it is still interesting to give accounts of the fate and occurrence of this pharmaceutical drug in a natural aqueous systems if environmental risks is of concern.

3.2 Ibuprofen concentration and mass transport in the Pasig River

Based from the literature (Table 1), the concentration of Ibuprofen in the Pasig River is relatively high if the natural aqueous systems (*i.e.* rivers and estuaries) will be looked into. The Pasig River's Ibuprofen concentration is close to the maximum values found in the UK estuaries. However, the Pasig River has higher minimum level (26 ng/L compared to <8 ng/L of UK estuaries). Also the range of concentration in the Pasig River is almost the same as what can be detected in the waste water treatment plants (WWTPs). Hence, it is important to note that the Ibuprofen concentration found in the Pasig River is in an alarming state.

Table 1. Environmental occurrence of Ibuprofen in the Aqueous Systems

Location/Aqueous System and Ibuprofen Concentration	Reference
Italy: Tap water 0.03 to 0.02 ng/L	[5]
Johannesburg: Goudkoppies WWTP: Influent: 40 ng/L; Effluent: 13 ng/L Northern WWTP: Influent: 112 ng/L; Effluent:25 ng/L	[7]
Italy: River: 0.67 ng/L; Tap water: 0.20 ng/L	[21]
San Francisco Bay water- max.: 37.9 ng/L	[22]
Mackinaw River Illinois, USA: Influent: 18 600- 26 200 ng/L; Lagoon: 1 840-13 900 ng/L; Effluent: 146-5 030 ng/L; Upstream: 1.77-4.65 ng/L; Downstream: 43.6-1 210 ng/L Mackinaw River: na-4.75 ng/L	[23]
Charleston Harbor, South California: WTP1: Influent: 14 317 ng/L; Effluent: 928 ng/L WTP2: Influent: 24 033 ng/L ; Effluent: 2 600 ng/L Surface water: 8 ng/L	[24]
NE, Spain Drinking Water Treatment Plant (DWTP), Raw water Conventional Treatment: Diox+sand filtered: 71-216 ng/L; Ozonated: 28-58 ng/L; GAC filtered: <LOD Advance Treatment: Ultrafiltration: 79-202 ng/L; Reverse Osmosis: <LOD; Remineralization: <LOD	[25]
South Wales, UK: River Taff: Usptream: 5-48 ng/L; Downstream: 12-62 ng/L WWTP Cilfynydd: influent: 968-2 986 ng/L; effluent: 131-424 ng/L River Ely: upstream: <0.3-56 ng/L; downstream: 4-74 ng/L WWTP Colsech: influent: 948-6 328 ng/L; effluent: 65-491 ng/L	[26]
Lower Tyne Catchment, UK, Howdown WTW: Raw: 7 741-33 746 ng/L; Pre-UV: 8 771-15 778 ng/L; Final: 1 979-4 239 ng/L	[27]
UK Estuaries: Mersey: <8 – 368 ng/L; Tyne: <8 – 698 ng/L; Thames: <8 – 928 ng/L	[28]

Environmental apprehension can be higher if mass transport will be considered. For example, the Pasig River Rehabilitation Commission reported that the water flow of the Pasig River can range from 12 m^3/sec to 275 m^3/sec [29]. This then can mean that an estimate of 0.32 to 230 mg/second or 27 to 19 911 grams per day of Ibuprofen can be received by this important highly urbanized river.

3.3 Implications of the persistence of Ibuprofen in the natural aqueous system

Knowing the persistence of this pharmaceutical drug on the natural aqueous systems is essential. If the environmental factors such as sunlight, suspended solids and microorganisms will be considered, persistence ($t_{1/2}$) of Ibuprofen in raw water (*i.e.* samples from rivers) is about 64 days and around 20 days for lake water [30]. Under a stirred condition added with NaCl, the half-life ($t_{1/2}$) of Ibuprofen is 59 days [8]. Knowing the half-life, in this case, enables determining the duration of the pharmacologic activity of Ibuprofen in the natural tropical aqueous system. Recent researches showed that exposing the organism to Ibuprofen poses threats. In the study of [31], sea urchin (*Psammechinus miliaris*) was exposed to Ibuprofen. Results showed that the concentration detected in the sea urchin affects sperm motility and fertilization. Exposure of a tropical freshwater Zebrafish (*Danio rerio*) to Ibuprofen influenced the hatch rate, motion, locomotion, and gene expression [32].

The study of [20], showed interesting results on assessing the toxicity of Ibuprofen on a diatom (*Navicula sp.*). It was observed that Ibuprofen at low level (0.1 to 1 mg/L) can stimulate algal growth. At higher concentration (>1 mg/L), however, Ibuprofen can threaten the algal growth due to photosynthesis inhibition. Thus, the presence of Ibuprofen can affect activities of the microorganisms in the natural aqueous systems. Moreover, it is found out that Ibuprofen is subject to photochemical transformation through decarboxylation then radical formation and eventually oxidation [33]. Transformation is comparable to aromatic ketones raising more concerns on ecotoxic risk [34]. Another physico-chemical condition like high DO can enhance pharmaceutical biotransformation [35]. Thus, affecting the fate of this pharmaceutical drug.

4 Conclusion

The fate and occurrence of one of the common over the counter drugs in the Philippines, known as Ibuprofen, was detected in the Pasig River. Different physico-chemical conditions were encountered during the three sampling campaigns. Period 1 has the highest concentration of Ibuprofen. This period can be described having the highest physico-chemical condition but with the lowest DO level. The lowest concentration of Ibuprofen was found during Period 2. Unlike, Period 1, the physico-chemical parameters were lowest during this period but the DO level was the highest. Period 3 has higher Ibuprofen concentration than Period 2. Its water temperature is almost the same in Period 1 with the highest level of salinity.

Ibuprofen case in the Pasig River is in alarming state this is as: (*1*) it can be detected in even in different physico-chemical conditions of the Pasig River; (*2*) the concentration level is not negligible as it can be compared to the concentration found in wastewater treatment plants; (*3*) its persistence exposes microorganisms; and (*4*) it poses possible environmental risks to the aquatic system and concerns on human health. Hence, further monitoring and assessments of Ibuprofen in this natural tropical aqueous system.

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