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A WATER QUALITY MONITORING EXERCISE WITHIN THE BRICK MANUFACTURING INDUSTRY

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ABSTRACT

Brick manufacturing is a water-intensive industry, which produces both large amounts of polluted process water due to its continued demand for cleaning of the equipment for the brick production and sewage due to staff activities. In addition, it may also contaminate, through routine activities like brick storage, surface water that is running through a brickyard. Characterisation of treated process water, treated sewage and surface water through a water quality monitoring exercise seems to be mandatory. Surface water samples were collected from two fixed stations, one corresponding to its entrance to the brickyard (Point A) and the other to the exit (Point B). Any difference regarding the monitoring parameters between the two may be significantly (but not entirely as the surface water system is not closed) attributed mainly to the effect of treated process water and treated sewage on them. In terms of surface water quality, analysis of the data showed that average pH values were always slightly alkali, with Point B having an increased value compared to Point A. The EC value was also slightly increased at Point B compared to Point A. Both changes at Point B are due to the addition of treated process water (Point D) and treated sewage (Point C) to Point B. However, the treated sewage has, by definition, a lower effect on changes at Point B than treated process water, as the flow rate of the former is negligible compared to the latter. TSS were low at both Points A and B meaning that the heavily polluted with solids used process water was treated efficiently. On the other hand, TDS were rather higher than TSS. In addition, TDS were higher at Point B than Point A, which was expected as it had already been found that the average EC of the latter was higher than the former showing consistency. Average DO concentrations were higher at Point B than at Point A indicating the positive impact of the brick works on the surface water system regarding DO. Average turbidity values at Points A and B are not indicative as turbidity is easily affected by rainfall, however, their recorded values via routine measurements showed that they were always in relation with their corresponding recorded TSS. COD, NH_4-N and PO_4^{-3}-P values were always very low at both points, indicating water of very good quality at the exit point B. That was expected as brick manufacturing industry does not cause significant deterioration in terms of organic load. Finally, regarding inorganic micropollutants, their concentrations at Point D were quite low ensuring as expected their low concentration values at the exit Point B as well.

Keywords: water-intensive industry, brick manufacture, water pollution, water quality, water quality monitoring

1. Introduction

Bricks are used continuously for the construction of buildings not only because of their favourable physical, mechanical and thermal properties, in particular their strength, durability and compactness, but also because they are an economical product made of cheap, abundant raw materials, (*e.g.* clay, sand) and are produced through a simple manufacturing processes, namely drying and firing (Bories *et al.,* 2014). However, brick manufacturing is a water-intensive industry requiring large quantities of water to be consumed both for the production of bricks and for the cleaning of the equipment for their production. Water embedded to the clay mixture normally evaporates during the drying and firing of the bricks, however, all water used for

cleaning purposes turns into polluted process water, which requires characterization and suitable treatment before being re-used or discharged into natural water bodies. Taking into account that the brick manufacture industry uses additives like barium carbonate to control the extent of the efflorescence problem, through which crystallized salts accumulate on the surface of the bricks affecting not only their aesthetic quality but also cause serious microstructural damage (Andres *et al.*, 2009), a water quality monitoring exercise is required. This is critical as barium salts dissolve in the cleaning water. Also, sewage produced by staff on-site, together with any potential alteration of the quality of the surface water running within the boundary of the brickyard due to daily routine activities on-site, enhance the need for carrying out the above-mentioned water quality monitoring exercise. Water quality monitoring provides basic information on the condition of the water under study and it can be carried out for a variety of purposes (http://water.epa.gov, last accessed Feb. 2012). In this work, the most important reason was to characterise waters and identify changes over time as well as identifying specific or emerging water quality problems that are directly connected with the operation of the brick plant in the area.

This work concentrates on water quality monitoring activities relating to Wienerberger, the world's largest manufacturer of bricks (http://www.wienerberger.co.uk, last accessed Feb. 2012) focusing on the brickyard that is located in Horsham, in West Sussex, in the UK. Despite surface water was collected from a number of sampling points and analysed during this experiment, this work will concentrate on monitoring pollution of surface water collected from the two regular sites (fixed stations), which indicate the entrance of surface water into the brickyard and its exit. Also, collection and characterization of treated process water (its treatment is based on the removal of turbidity of clay suspensions with the addition of slightly anionic polyacrylamide flocculant) and treated sewage, took place. Water quality data such as dissolved oxygen (DO) concentration and its relative percentage, hydrogen ion exponent (pH), electrical conductivity (EC), turbidity and temperature (T), that are usually used to monitor the water pollution levels (Chung and Yoo, 2015), were measured on-site immediately after the collection of the samples, as well as further pollutant monitoring of both organic and inorganic nature, together with solids and their fractions, took place at the laboratory after having preserved the samples accordingly (Handbook for Sampling and Sample Preservation of Water and Wastewater, 1982). In particular, it was measured the concentrations of total solids (TS) and its fraction of total suspended solids (TSS), the chemical oxygen demand (COD), fractions of nutrients, namely the ammoniacal nitrogen (NH_4^+-N and the orthophosphates PO_4^{-3}-P), as well as concentrations of dissolved trace inorganics, mainly Ba.

2. Materials and methods

Samples were collected manually as manual sampling is a well-suited process for the collection of a small number of samples that was required for this research. Samples were collected three times a week in the morning regardless of the weather conditions. However, as every manual sampling process the samples can always be subject to an increased variability due to their sampling handling and some inconsistency in collection (Handbook for Sampling and Sample Preservation of Water and Wastewater, 1982).

Regarding monitoring parameters, COD, ammoniacal nitrogen and orthophosphates were measured through the HACH Methods (http://www.hach.com, last accessed in Feb. 2012), by using vials and a HACH DR/2800. These methods that are always compatible to standard methods. Total solids and total suspended solids concentrations were measured using the 2540 standard methods (Standard Methods for the Examination of Water and Wastewater, 2005). pH, EC, T and turbidity were measured with the use of suitable probes. Turbidity was measured with a turbidity meter capable of measuring turbidity values up to 1000 FTU and DO concentration and relative percentage were measured with the aid of a portable DO-meter with altitude and salinity concentration being accepted to be sea level and 0 respectively. Finally, trace inorganics were measured by using the analytical method of inductively coupled plasma atomic emission spectroscopy (ICP-AES).

For simplicity's sake, the entry point will be Point A, the exit point will be Point B, treated sewage will be collected from Point C and treated process water from Point D.

3. Analysis of the data and results

All results regarding this work are summarised below either in figures or tables. Table 1 summarises the average values of the parameters that were measured on-site for all four sampling points.

Table 1: Summary of the parameters measured on-site

Parameter/Points	Point A	Point B	Point C	Point D
pH (-)	7.37	7.91	7.03	8.27
EC (cm S^{-1})	0.68	0.78	0.65	0.86
DO (mg L^{-1}/%)	4.27/40.85	7.73/75.87	5.04/51.43	8.77/88.44

Analysis of the data shows that the average pH values were always slightly alkali, with Point B having a slightly increased value regarding to Point A, which can be attributed to the fact that pH of Point D is of the highest value. As treated process water is discharged at Point B, pH at the exit point consequently increases. However, all pH values indicate that all streams are acid-free. Regarding the EC, its value was also slightly increased at Point B compared to Point A something that can be explained as before, as again EC value at Point D is the highest, consequently it increases the EC at Point B. This indicates that, even though the concentration of [H$^+$] is lower at the exit, the total concentration of all ions is larger indicating that treated water contains a significant amount of TDS that affect the EC value at the exit. Finally, the DO concentration levels at the exit are quite high as the relative DO percentage was equal to 75.87%. Turbidity values, in particular, for Points A and B were most of the time between 0 and 150 FTU for both streams, however, as it is a value which can be affected by storm water run-off, increased values were also recorded. At this point, it is worth mentioning that, even though the quality of water at Point C has also contributed to the final water quality at Point B, something that it is in line with the measurements, its effect is rather decreased as its volumetric flow rate is negligible when compared to the volumetric flow rate at Point D.

Figures 1 and 2 show the courses of TSS (measured) and TDS (estimated as the -difference between the TS and the TSS). The figures show that at both Points A and B, the TSS concentrations are usually quite low, below 50 mg L^{-1}. When higher concentrations are recorded, are mainly due to the agitation of the streams. These higher values can additionally be supported by the higher turbidity values that were also recorded. At this point, it is worth mentioning that the unit that treated polluted process water via flocculation, managed to reduce significantly the amounts of TSS in the supernatant - the average removal efficiency was equal to 95.7%. On the other hand, TDS appeared to be higher than TSS in general. In addition, TDS are always higher at Point B than at Point A, which is also in line with the average EC values at these points.
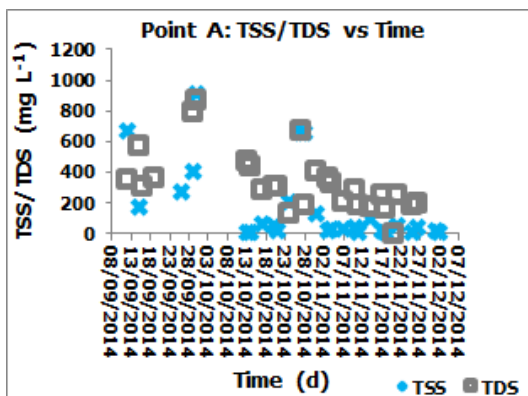

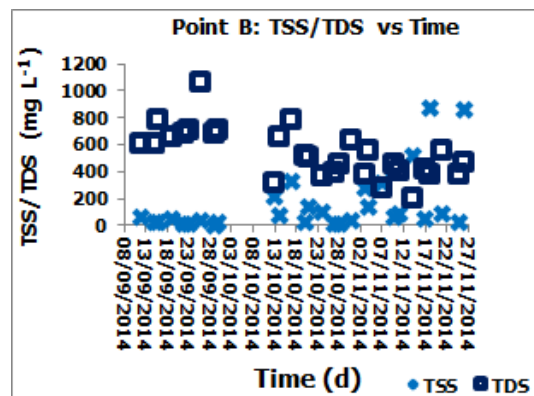
Figure 1: TSS and TDS at Point A

Figure 2: TSS and TDS at Point B

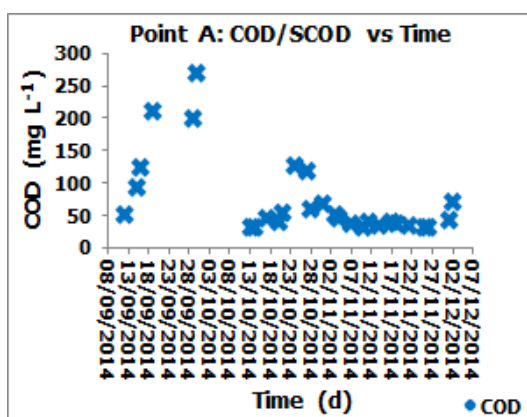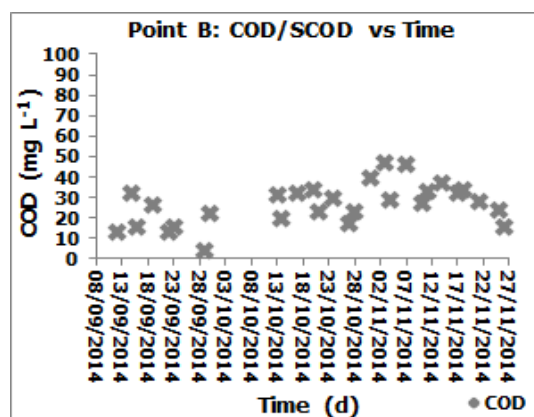Regarding COD, Figures 3 and 4 can be drawn.

Figure 3: COD at Point A
Figure 4: COD at Point B

Regarding COD values, it can be seen that at both Points A and B, the COD values are quite satisfactory being at both points, for most of time, below 50 mg L^{-1}, thus, indicating excellent water quality. Some higher values at Point A, in particular at the beginning of the experiment, are because the collection of the samples was without due flow rate with stagnant water having been expected to be loaded with additional organic pollution. Finally, regarding the fractions of nutrients that were measured, it was found that the average values of NH_4^+-N and PO_4^{-3}-P were very low, namely 0.55 mg L^{-1} and 1.68 mg L^{-1} respectively for Point A and 0.77 mg L^{-1} and 1.21 mg L^{-1} respectively for Point B.

Regarding trace inorganics, the following Table 2 can be created. As seen in Table 2, the concentration values of metals at Point D, who is the main feed of Point B, are quite low - flocculation of clay suspensions might have also helped in acquiring these low values as the anionic/non-ionic polymers are effective at removing dissolved metals, however, for a more enhanced performance, they are usually combined with ferric chloride (Johnson *et al.*, 2008, Amuda *et al.*, 2006).

Table 2: Concentrations of Trace Inorganics

Concentration (mg L^{-1})/Points	Point A	Point B	Point D
Cd	0.0007	0.0010	0.0005
Cr	0.0010	0.0097	0.0022
Cu	0.0433	0.0217	0.0077
Pb	0.0000	0.0006	0.0000
Zn	0.0463	0.1086	0.1520
Ni	0.0033	0.0236	0.0068
Mn	0.0990	0.3436	0.1943
Fe	0.0373	0.2765	0.2760
Co	0.0003	0.0031	0.0027
Mo	0.0040	0.0046	0.0054
Ba	0.2587	0.3091	0.2955
Al	0.2167	1.1664	1.0950
Ti	0.0103	0.0118	0.0111

Concentrations at Point B are, for the majority of trace metals, higher than those at Point A. Partly, this can be attributed to the slightly higher concentrations at Point D than at Point A. As concentrations at Point D are not high enough to increase those at Point B to the detected values and as treated sewage both in terms of quantity and quality is not expected to lead to

such an increase, these increased final values should be attributed to surface runoff and/or other water streams that may end up at Point B. However, the concentrations of most of them at the exit are quite low, with those for Ba close to the limits set for primary drinking water (http://water.epa.gov, last accessed in Feb. 2015).

4. Conclusions

This work concentrated on a water quality monitoring exercise regarding the effect a brick manufacture industry has on surface water within its boundary. The exercise showed that the brickyard may at times deteriorate the initial surface water quality, however, the change is most of times negligible. This was expected as the brick manufacturing is an almost chemical-free industry mainly dealing with clay and sand.

REFERENCES

1. Amuda O., Amoo I., Ipinmoroti K., Ajayi O. (2006), Coagulation/Flocculation Process in the Removal of Trace Metals present in Industrial Wastewater, J. Appl. Sci. Environ. Manage., **10**, 159-162
2. Andrés A., Díaz C.M., Coz A., Abellán J.M., Viguri J. R. (2009), Physico-Chemical Characterisation of Bricks all through the Manufacture Process in relation to Efflorescence Salts, J. Eur. Ceram. Soc., **29**, 1869-1877
3. Bories C., Borredon M.-E., Vedrenne E, Vilarem G. (2014), Development of Eco-Friendly Porous Fired Clay Bricks using Pore-Forming agents: A Review, J. Environ. Manage., **143**, 186-196
4. Chung W.-Y. and Yoo J.-H. Remote Water Quality Monitoring in Wide Area (2015), Sens. Actuators, B, In Press
5. Handbook for Sampling and Sample Preservation of Water and Wastewater (1982), EPA-600/4-82-029, Environmental Monitroing and Support Laboratory, Office of Research and Development, U.S. EPA, Cincinatti, Ohio, 45268
6. Johnson P. D., Girinathannair P., Ohlinger K. N., Ritchie S., Teuber L., Kirby J. (2008), Enhanced Removal of Heavy Metals in Primary Treatment using Coagulation and Flocculation, Water Environ. Res., **80**, 472-479
7. http://www.hach.com, last accessed in Feb. 2012
8. http://water.epa.gov, last accessed Feb. 2012
9. http://www.wienerberger.co.uk, last accessed Feb. 2012
10. Standard Methods for the Examination of Water and Wastewater 2005 21st Edn, American Public Health Association/American Water Works Association/Water Environment Federation, Washington, DC, USA