Fast-Track in-Stream Action to Enhance the Oxidative Capacity within Watershed

Mohamed L. ElKhazragy, Minerva E. Matta, Khaled Z. Abdallah

Abstract: ***This work presents a non-conventional alternative for cleaning polluted agriculture drainage network within a certain watershed. In Egypt, a need for using marginal quality water in agriculture applications is becoming a great necessity due to water shortage. One important strategy to increase available water resources is to reuse agriculture drainage water for irrigation application. The water system, especially drainage network receives a remarkable amount of pollution (raw and partially treated wastewater). That results to an increase in organic load to an unacceptable level, accordingly, the water quality of the drainage water has been negatively affected and the "reuse" plan has been threatened. Fast-Track In-stream Action (FTIA) is an ongoing fast action suggested to control the pollution of drainage water within a certain watershed to make it more suitable for reuse practice. FTIA as a quick interfere will skip long-term processes of conventional water treatment stages to get satisfactory results in proper time. It presents a practical immediate solution to achieve acceptable level of water quality rather than waiting for full improvement through long-term and expensive conventional programs. In this study a biological maintenance solution was applied and tested in both bench and field scales to assess its efficiency in improving the water quality within selected watershed. An evaluation of this fast-track process was done by measuring a significant key water quality parameters (WQPs) at designed locations of the study area before, during and after application of material. For better explanation of overall water quality and proper comparison, a weighted arithmetic water quality index (AWQI) has been discussed based on eight selected WQPs. In addition to a bench-scale test, two other field investigations were adopted: the first one investigates the effects of fast-track resources when applying the bio-based material under high flow condition with intermediate shock flow (study area "1"), while the other one examine the application of material under low flow condition with intermediate shock pollution load (study area "2"). All indicators, including aesthetics showed improvements in selected WQPs and AWQI during the investigation period***

Keywords: Bio-based material, Drainage water reuse (DWR), Fast-track action, GIS, Point source of pollution (PSP), Water quality management, Watershed, Water Quality Index (WQI).

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I. INTRODUCTION

In Egypt, the Nile River supplies 73% of fresh water directly to different usages, while the reminder mostly comes indirectly from the reuse of drainage water [1]. The rapid deterioration in water quality is one of the most important factors that increase the stress on Egypt's water resources. Water of good quality is becoming increasingly scarce and therefore more costly, One strategy to increase available water resources is to reuse agriculture drainage water. The detrimental effects of drainage water reuse can be minimized by adopting appropriate pollution sources management.

In this study, a fast-track action strategy has been proposed: Fast-Track In-stream Action (FTIA) strategy can be achieved by introducing the following tools: 1- fast-track scheme to easily describe the target watershed by using Geographical Information System (GIS) [2] and using 2- fast-track resources as a bio-based material to directly target the hot spots within the watershed. Fast-track action strategy as a quick interfere is a practical and unconventional solution to achieve an immediate partial improvement of present water quality and environmental status within a certain watershed. The watershed as a fast track-scheme is a premier water system unit for best management rather than administration boundaries scheme, where whatever is dumped in watershed's upstream ends up downstream. The primary field investigation showed that the main pollutant in the drains is organic contamination, which is impacting a number of key WQPs. The fast-track resource used in this study is a bio-based material that has several applications including agriculture, composting, and bioremediation. It provides a sustainable risk free alternative to any biological system and are manufactured as dry powder.

Problem statement

The low level of sanitation service especially in rural areas makes nearby streams (either canals or drains) the perfect places for inhabitants to dispose of their sewage [3]. With the continuous pollution dumping to the water system, the capabilities of a natural system to process the pollution is getting low. Most water policies adopted traditional strategies with continues dumping in water streams without serious consideration to its environmental effects on downstream, even when be considered, they were superficially touched within isolated administration boundaries.

Lack of investment and time required to complete establishment of planned conventional wastewater treatment plants (WWTPs), become a constrain impeding the improvement in surface water quality. Furthermore, the majority of existing WWTPs are aging and overloaded and facing the problem of lack of investment for operation and maintenance. The need to fast-track action strategy within watershed boundary rather than administration one, as an emergency management alternative is getting urgently needed nowadays.

II. MATERIAL AND METHODOLOGY

FTIA carried out a validation program using bio-based material to enhance the oxidative capability of the selected streams within the study area. The fast-track resources used in this study is a bio-based non-hazardous, non-toxic material. It is a combined blend of microorganisms, enzymes, and co-factors. The material was produced from naturally, no genetically modified microorganisms (GMO). The bio-based material that has been selected for this study is called "BiOWiSH Aqua" by BiOWiSH Technologies International Inc. originated from United State. It was found to be effective in restoring water quality under appropriate conditions. It acted as a powerful biocatalyst to improve the biological transformation of polluted water. The fast-track resources bio-based material can be applied either along the stream (drains, canals) or at the point sources of pollution (e.g., low efficiency WWTPs, septic tanks and fish farming). The evaluation has been conducted by testing the material in two stages as illustrated in diagram figure 1: - bench scale test under manageable conditions; and - In-field test, with intermediate shock flow and load. In stage 1 a "fast-track analysis" has been carried out by measuring a significant key WQPs of a nearby heavily polluted drainage water under laboratory conditions (bench-scale test). In stage 2 a "fast-Track analysis" has been carried out at designed locations (surface water) of heavily polluted surface water (study area "1" and "2"), before, during, and after applying the bio-based material. A distance ranged from 250 to 800 m was chosen to test the capability of biocatalysts to break down the pollutants. The analysis was carried out and verified by three accredited official laboratories. The output results were used in comparing WQPs and calculating AWQI. AWQI is regularly used as simple tools to provide a single number that expresses overall water quality at a certain location and time and summarizes WQPs into simple description (e.g., excellent, good, bad, etc.), for reporting to managers and the public in a consistent manner [4].

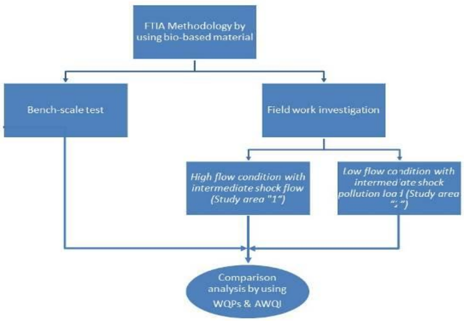


Figure 1: Methodology flow chart

III. DISCUSSION

Water quality index calculation

The calculation of the WQI was done using weighted arithmetic water quality index (AWQI) [5] as in the following form:

$$AWQI_A = \sum_{i=1}^{n} w_i q_i \Big/ \sum_{i=1}^{n} w_i \qquad (1)$$

Where n is the number of variables or parameters, W_i is the relative weight of i^{th} parameter and q_i is the water quality rating of i^{th} parameter. The unit weight (W_i) of the various WQPs are inversely proportional to the recommended standards for the corresponding parameters. The value of q_i is calculated using the following equation:

$$q_i = 100\,[(V_i - V_{id}) / (S_i - V_{id})] \qquad (2)$$

Where V_i is the observed value of i^{th} parameter, S_i is the standard permissible value of i^{th} parameter and V_{id} is the ideal value of i^{th} parameter. All the ideal values (V_{id}) are taken according to the acceptable level of chosen parameters. The calculation of AWQI was carried out in three main steps: 1- parameter selection; 2- assignment of parameters weights and 3- aggregation of sub-indices to produce a final index score.

Parameters selection, weighted and standards

The basic function of any WQI is to consolidate several concentrations for different WQPs into a single numerical value. However, the importance of these parameters is mainly attributed to the possible water use [6]. The selection of WQPs and assigning their relative importance related to the drainage water reuse (DWR) in irrigation and fish farming were carried out by studying previous efforts in this field and that parameters which are affected by applying the bio-based compound and weighted accordingly (Table 1). For the selected WQPs, national standards (law 48 for the year 1982 and related amendment for the year 2013) were used as reference for setting parameters standard values. It is clear that the highest weights were given to the WQPs: BOD, COD, and TSS, where those parameters are essential in describing the biological pollution. In addition, oil & grease levels in water are of prime concern in different applications.

Table 1 - Selected WQPs and their assigned weights and standards

Parameter (WQP)	Water Quality Standard	Weight
BOD (mg/ L)	10	0.23
COD (mg/ L)	15	0.21
TSS (mg/ L)	50	0.25
FC (MPN/ 100 ml)	5000	0.01
NH_3 (mg/ L)	0.5	0.04
TP (mg/ L)	3	0.01
FS (MPN/ 100 ml)	100	0.01
DO H_2S (mg/ L)	5	0.08
Oil & grease	1	0.17
E. col (MPN/ 100 ml)	5000	
∑		1

Notes: BOD: biological oxygen demand; COD chemical oxygen demand; TSS: total suspended solid; FC: fecal coliform; TP: total phosphorus; FS: Fecal streptococci; DO: Dissolved oxygen; H_2S: Hydrogen sulphide. E. coli: Escherichia coli

Bench-scale test

The bench-scale test was conducted for fourteen days' period (the time life of the bacteria of bio-based material is nine days). The test aims to verify the oxidative capability of the bio-based material under controlled conditions within confined polluted water body. The dosing solution has been prepared according to company's recommendations, by adding 25 gm of compound into 25 liters of water and mixing properly (steering and aeration) for 4 hours (concentration of solution was 1 gm/liter). A sample of 100 liters was collected from its original source (agriculture drain) and send to the laboratory for investigation in isolated iced tank. The 100 liters' ambient sample was divided into two. The first 50 liters was the control sample (CS), while the other 50 liters was the test one (TS). 250 ml of dosing solution was added to the test tank with steering (concentration of ambient water 5 mg/ liter), and add maintenance dose to the test tank of 100 ml on the fifth day. A set of 46 WQPs were tested to evaluate the capabilities of the material to clean ambient sample under controlled conditions (bench scale), while only eight WQPs: BOD; COD; TSS; NH_3; FC; H_2S; FS and E. coli were selected for AWQI calculation.

Field work (surface drainage water)

Prior to field investigation, a preliminary field test was conducted to detect the level of pollution in ambient water and to ensure the suitability of surface water to accommodate the bio-based material in terms of the salinity and toxicity. The pre-investigation process shoes that the Ammonia (NH_3) saturation parameter at the sampling location of study area "1" was 3.5 mg/ liter, indicating a heavy organic pollutant load, the chemical oxygen demand (COD) was 71 mg/liter in addition to a remarkable microbiological and biological contamination. The measured toxicity of ambient water has not reached the critical level on microorganism of the bio-based material, so it is suitable for bio-based material to be applied.

The second step was to apply the bio-based material to polluted open streams under variant conditions of discharge, contact time and load of pollution as follows: 1-Extreme flow condition (in the study area "1", the discharge ranged from 100,000 (low flow) to 900,000 m^3/day (shock flow) with an average of 500,000 m^3/day) and low contact time (8 minutes for drain "1", 1.6 hours for drain "2"). 2- The second condition was: Low flow condition (case study "2" of a discharge of 20,000 m^3/day) with a shock polluted load and contact time of (0.45 hours). The eight selected WQPs for AWQI calculation are: BOD, COD, TSS, NH_3, FC, DO, TP and oil & grease

IV. APPLICATION & RESULTS

Bench-scale results

For WQPs results, figure 2 shows the measured results for both control (CS) and test samples (TS) for the selected WQPs. The figure illustrates the overall improvement in WQPs values over the period of bench-scale test (14 days) and relative improvement between CS and TS along the same period as summarised in table 2.

The AWQIs (Table 3 and graph Figure 3), illustrate the improvement in AWQIs of selected WQPs. The best effect of the bio-based material ranged between "22%" to "26%" during 14 days of application.

Table 2 - Overall/ relative improvement in WQPs – bench-scale test

Parameter (WQP)	Max. Relative improvement TS/ CS %	Overall improvement TS %
BOD	27% @ H12	71
COD	16% @ H8	70
H_2S	47% @ H48	97
TSS	66% @ H24	88
NH_3	27% @ H8	73
E. coli	30% @ H24	100
FC	20% @ H168	100
FS	61% @ H12	100

Notes: CS: control sample; TS: test sample

Table 3 - AWQI and improvement percentage for bench-scale test

	WQI							
	H_0	H_4	H_8	H_{12}	H_{24}	H_{48}	H_{168}	H_{336}
CS	366	356	341	319	290	246	169	112
TS	366	321	270	257	216	193	136	93
Improving	0%	10 %	21 %	20%	26 %	22 %	19 %	16 %

Notes; Hn: WQI at hour n; TS: test sample; CS: control sample

Field work (surface drainage water)

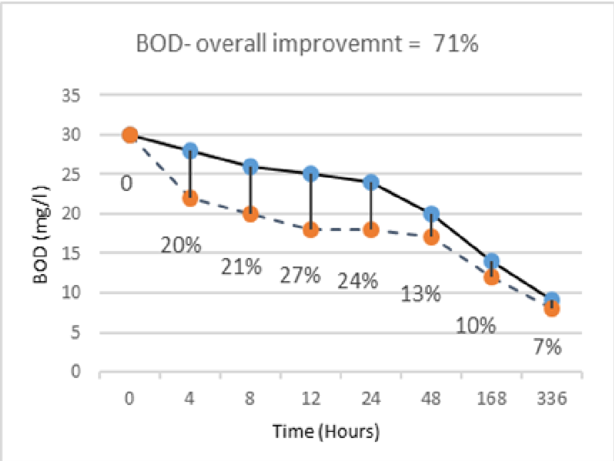
Study area "1": High flow condition with intermediate shock flow

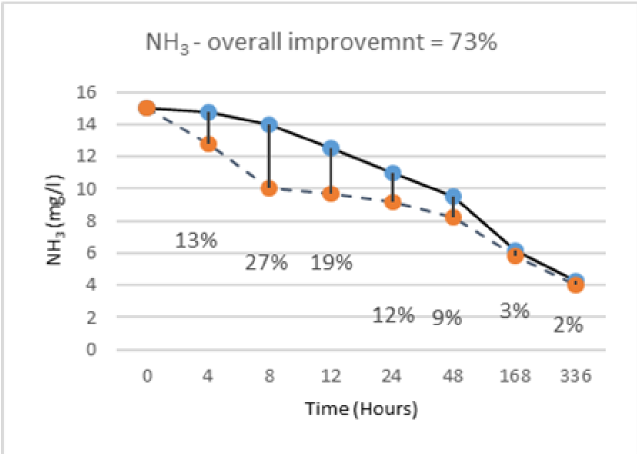
The field investigation has been conducted over 27 days. For experimental work, the proposed study area has an agriculture drain "1" discharges directly into main drain "2" at km 19.85 as illustrated in figure 4. The drains were selected for this study as an actual case study, where it receives discharge from predominantly untreated or poorly treated domestic and industrial wastewater, and drainage return flow from agriculture land and fish farming. The dosing solution was prepared by mixing the compound in fresh water. The result of this process is an active aqueous solution, which can be dosed into the water system. The process requires 20 ~ 50 L of fresh water per kg of product. For the study area, the dosing rate has been designed as shown in table 4 based on the designed average discharge of 500,000 m^3/ day.

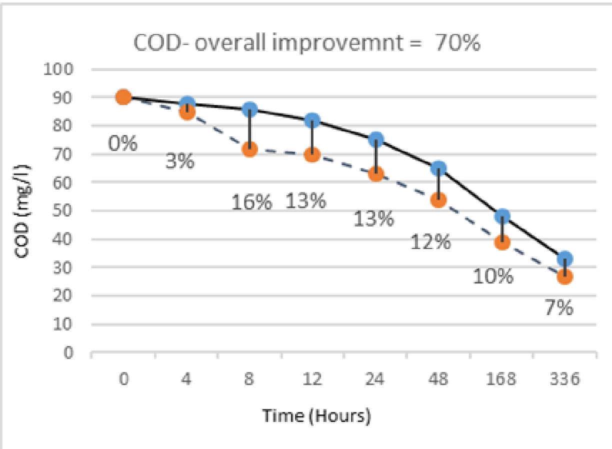
Table 4: Dosing rate & schedule

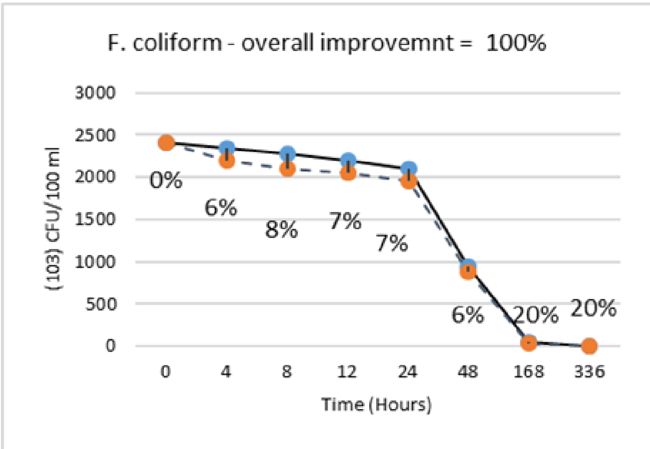
Day	Material added (kg/ day)	Q_{Ave} 1000 m^3/day	Ambient concentratio n mg/L
1	275	110.2	2.5
2	225	716	0.3
3and 4	175*2	761.9*2	0.2
5	150	881.3	0.2
6 and 7	125*2	798.7*2	0.2
8 and 9	100*2	587.5*2	0.2
10 and 11	80*2	422.3*2	0.2
12 to 15	75*4	477.4*4	0.2
16 and 17	50*2	807.8*2	0.1

A set of two tanks of size 3 m^3 each have been installed at the outlet of drain “1” as in figure 5, to activate the material. Five tanks of size (0.5 m^3) were used for dosing. The dosing station was chosen at the outlet of the rising pump station (Figure 4), where the process was as follows:









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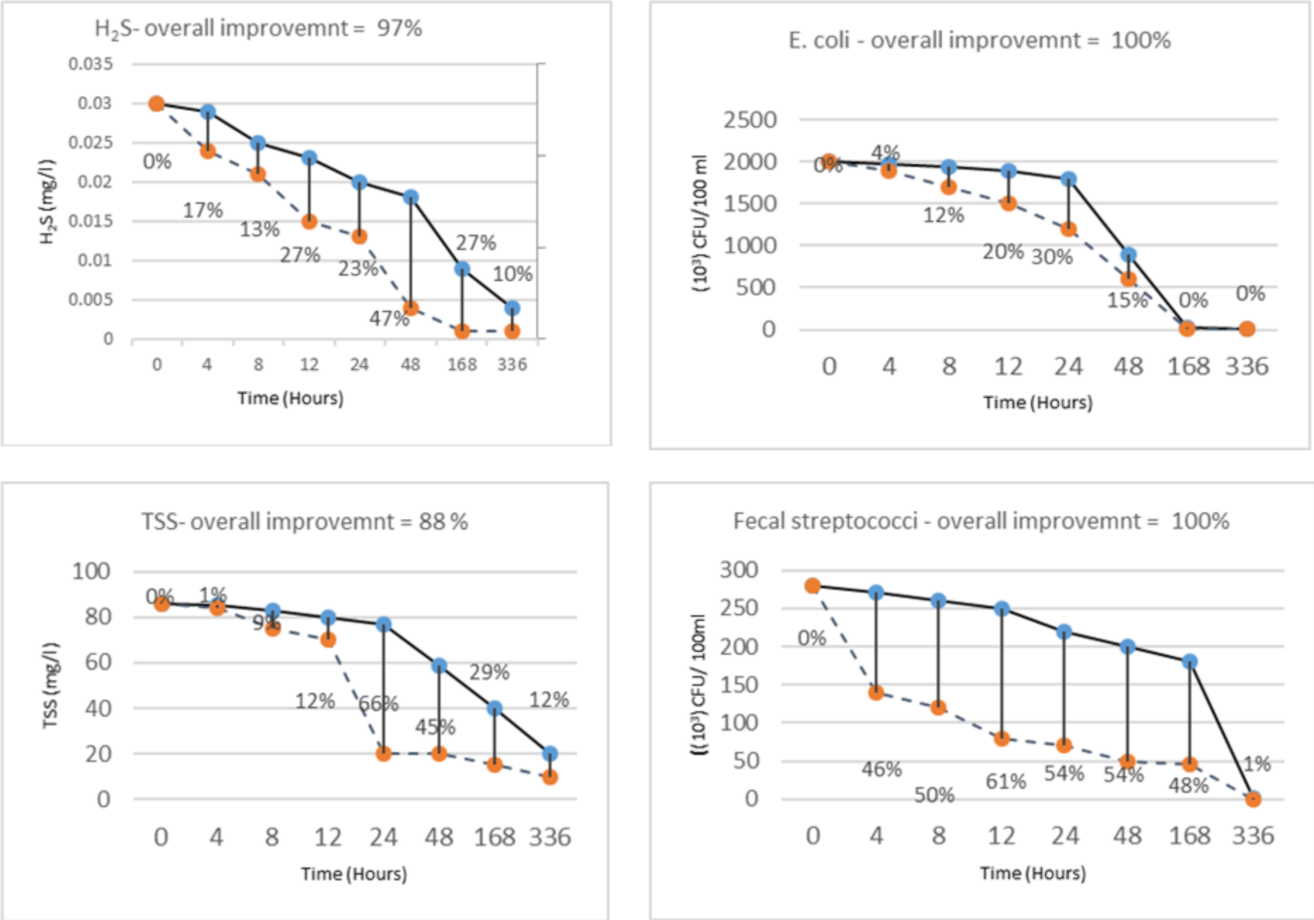


Figure 2: Measured values, percentage and overall improvement of selected WQPs (Bench scale)

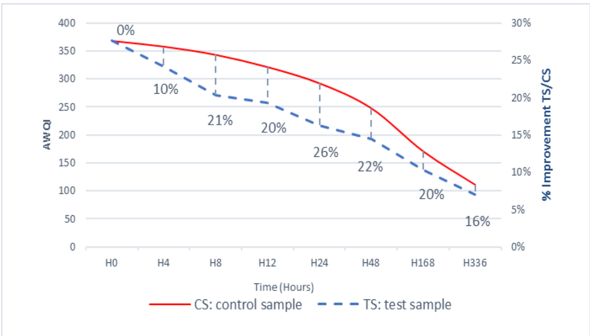
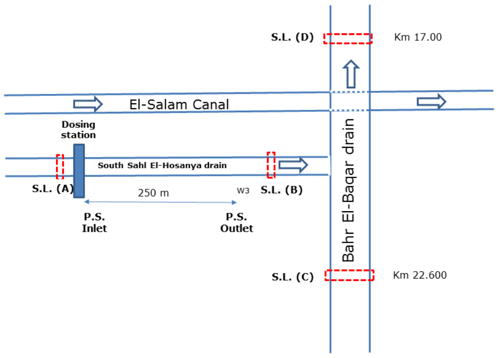


Figure 3: AWQI improvement for bench-scale test



Note: S. L.: sampling location, P.S.: pump station

Figure 4: Samples locations (surface water and sediment) for drain 1, 2 of study area "1"

Figure 5: Dosing station

- Place the required mass of compound into the tank and fill with water, - Apply a mix process up to 5 hours, - Place the tank to the designated dosing location and run a hose down into the dosing point with an estimate rate of 10 L/min.

A set of samples have been collected from four different locations (S.L) as shown in figure 4, over 27 days of investigation, according to following designed time schedule: at 1^{st}, 6^{th}, 9^{th}, 13^{th}, 15^{th} day of application and 6^{th}, 10^{th} day after application. A daily monitoring of discharge has been recorded. Samples were assessed for around 44 physio-chemical and biological WQPs for field investigation. However, pH, Temperature (T) and DO were measured in situ using a portable meter.

For the WQPs results: Figure 6 and table 5, shows the measured values for the 4 sampling locations (S. L. (A), (B), (C), (D)) for the selected WQPs. The figure illustrates the overall improvement in WQPs values over the period of field investigation (27 days) and relative improvement between S. L. (B)/ (A) (Stream "1") and S. L. (D)/ (C) (stream "2") along the same period as summarised in table 5.

Table 5: Relative improvement in WQPs – study area "1"

Parameter (WQP)	Max. Relative improvement S.L. (B)/ S. L. (A)	Max. Relative improvement S.L. (C)/ S. L. (D)
BOD	24% @ D15	40% @ D13
COD	26% @ AD6	21% @ D9
DO	15% @D7	-10% @ D13
TSS	47% @ D6	61% @ D6
NH_3	37% @ D15	43% @ D13
TP	34% @ D1	27% @ D6
FC	64% @ D2	78% @ D13
Oil & grease	50% @ D6	57% @ D6

For AWQI results: The highest improvement in AWQI ranged from “21%” to “26%” (Table 6, Figure 7);
- At the time of maximum capacity of raising pump station (maximum irrigation water requirements period), in addition to the slightly effect of bio-based material, the AWQI was greatly affected by dilution (the biological contamination in drainage water is relatively small).
- The slightly effect of the material was noticeable in drain “2” of study area “1” where changing in odor and water transparency has been recognized at S. L. (D) (3 km downstream drain “1”).

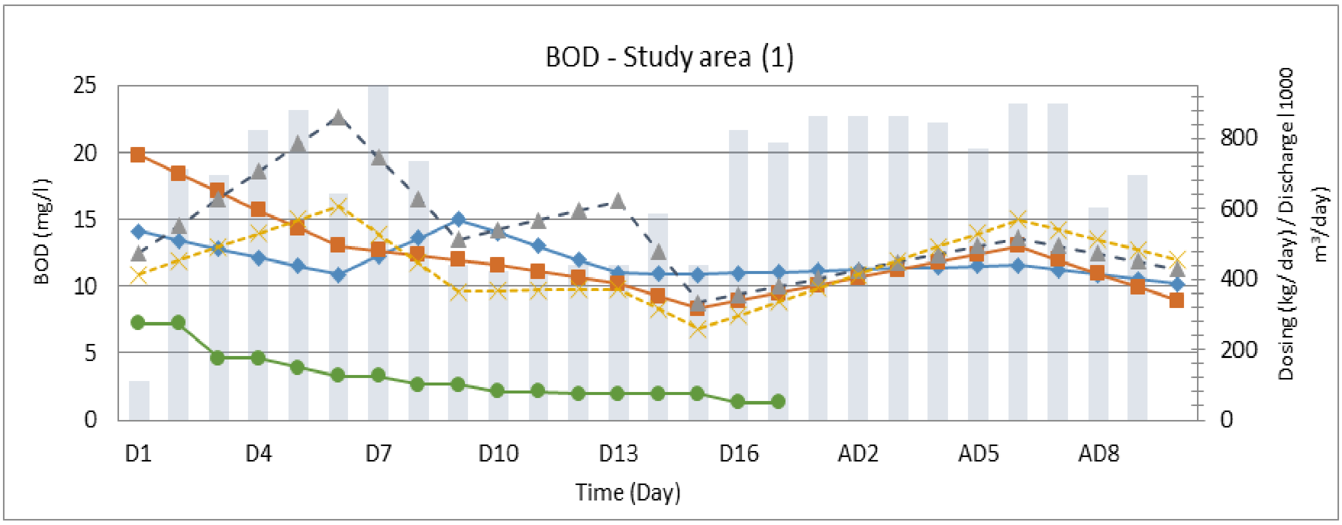
Study area “2” Low flow condition with intermediate shock pollution load

The field investigation has been conducted along 38 days on the canal of study area “2”. It is an un-official canal that is fed directly from drain “2” of study area “1” by two main pipes of one-meter diameter each, with an average measured discharge of 20 m^3/day, length is 5 km and water applications are irrigation and fish farming.

For implementation and dosing: One main tank of size 3 m^3 has been used as mixer to activate the material and other one tank of size 0.5 m^3 for dosing. The dosing station for the activated product was chosen at a distance of 500 m away from canal’s intake. The dosing rate has been designed as listed in table 7, based on average canal’s discharge of about 20,000 m^3/day. Samples have been collected from three different sampling locations (Figure 8) over a period of 38 days as following schedule: 3rd, 7th, 10th, 14th day of application, and 1st and 2nd day of post application.

For WQPs results: figure 9 and table 8, shows the measured values for the 4 sampling locations (S. L. (A), (B), (C)) for the selected WQPs. The figure illustrates the relative improvement in WQPs values over the period of field test (38 days) between S. L. (C)/ (A) and S. L. (B)/ (A) as summarised in table 8.

For AWQI results: A sudden shock polluted flow discharged from a branch which located few meters from S. L. (B). The shock flow came from a fish farming draining water.
-The highest improvement in AWQI ranged from “13 %” to “16 %” happened at S. L. (C) after receiving the shock pollution load during the application of material.
- The effect of the bio-based material was noticeable on study area “2”, where changing in odor and transparency of water has been recognized at point S. L. (C) at day D21 up to the end of field work.



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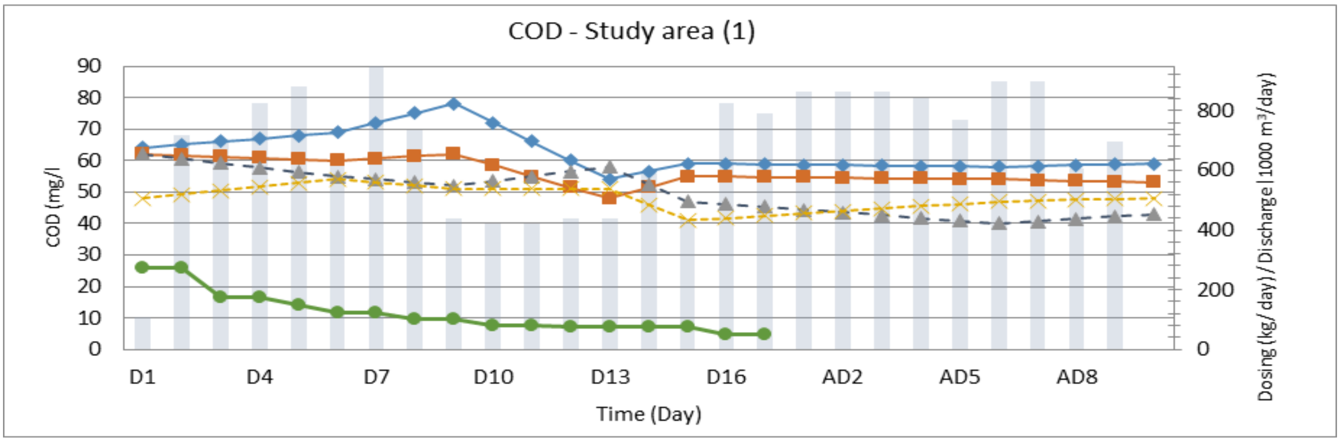
COD - Study area (1)
COD (mg/l)
Dosing (kg/ day) / Discharge (1000 m³/day)
Time (Day)
D1
D4
D7
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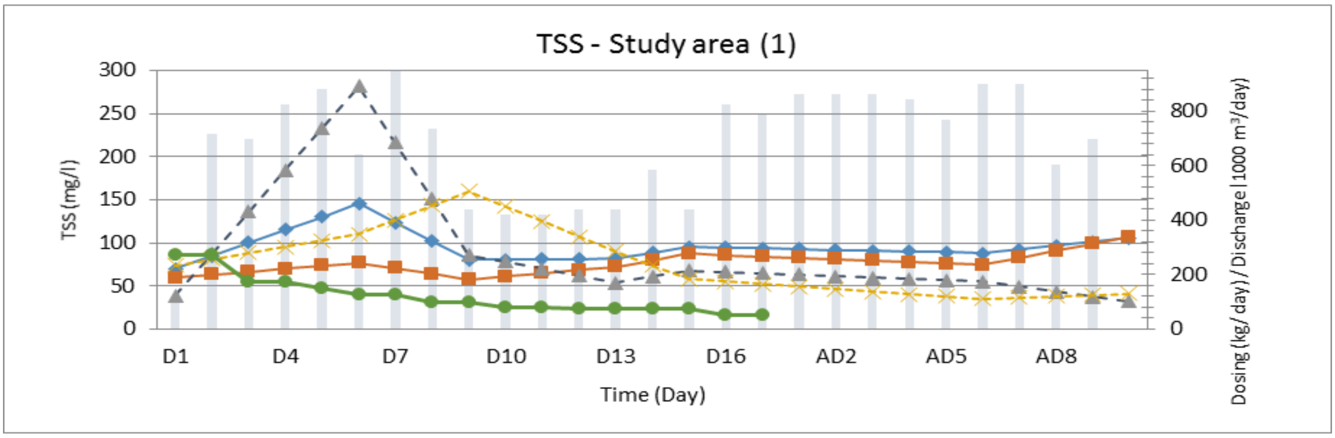
AD5
AD8


TSS - Study area (1)
TSS (mg/l)
Dosing (kg/ day) / Discharge (1000 m³/day)
Time (Day)
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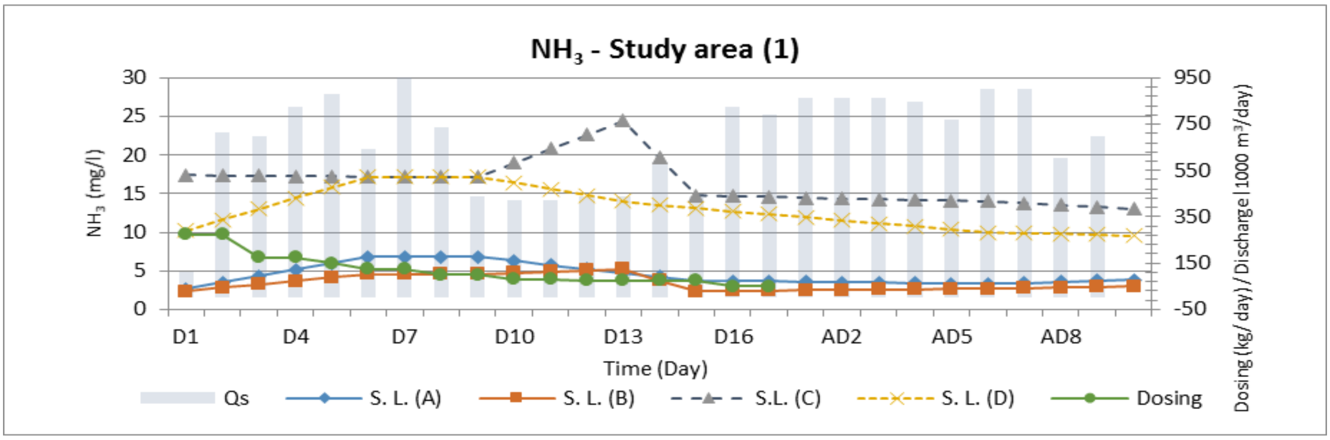
D16
AD2
AD5
AD8


NH3 - Study area (1)
NH3 (mg/l)
Dosing (kg/ day) / Discharge (1000 m³/day)
Time (Day)
D1
D4
D7
D10
D13
D16
AD2
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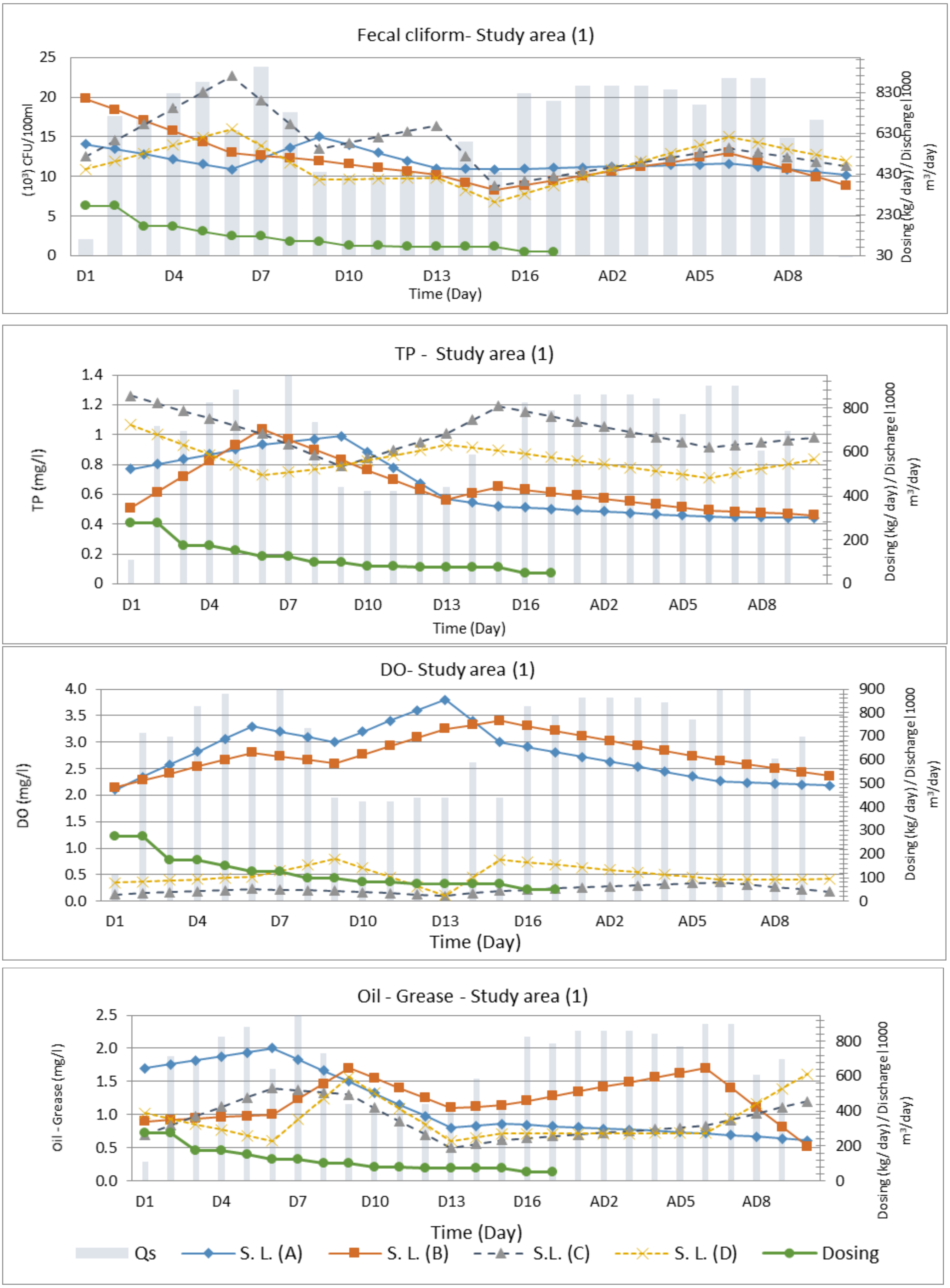


Figure 6: Measured values, percentage and overall improvement of selected WQPs (study area "1")

Table 6: Results of AWQI for study area "1"

Item	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13
S. L.(A)	367	356	346	335	325	314	350	386	422	415	408	402	395
S. L. (B)	272	267	262	258	253	248	283	317	352	361	371	380	389
S. L. (C)	405	383	361	339	317	295	313	331	350	421	492	564	635
S. L. (D)	300	293	286	279	273	266	286	306	326	364	402	440	477
Q	110	716	698	826	881	643	955	734	441	422	422	441	441
Dosing	275	275	175	175	150	125	125	100	100	80	80	75	75
Reduction % (S. L. (A) – S. L. (B))	26%	25%	24%	23%	22%	21%	19%	18%	17%	13%	9%	5%	1%
Reduction % (S. L. (C) – S. L. (D))	26%	24%	21%	18%	14%	10%	9%	8%	7%	13%	18%	22%	25%

Item	D14	D15	D16	D17	AD1	AD2	AD3	AD4	AD5	AD6	AD7	AD8	AD9	AD10
S. L.(A)	399	403	391	380	368	356	344	332	321	309	290	271	252	233
S. L. (B)	375	360	353	346	340	333	326	319	313	306	284	262	240	218
S. L. (C)	550	464	449	434	419	404	389	373	358	343	323	302	282	262
S. L. (D)	449	422	409	396	383	371	358	345	332	319	302	285	268	251
Q	588	441	826	789	863	863	863	845	771	900	900	606	698	
Dosing	75	75	50	50										
Reduction % (S. L. (A) – S. L. (B))	6%	11%	10%	9%	8%	6%	5%	4%	2%	1%	2%	3%	5%	7%
Reduction % (S. L. (C) – S. L. (D))	18%	9%	9%	9%	8%	8%	8%	8%	7%	7%	6%	6%	5%	4%

Notes: S. L. (n): Sampling location number n, Q: recorded daily discharge, Shaded cells where bio-based material was applied, where, Dn: day of application, AP: post-application day.

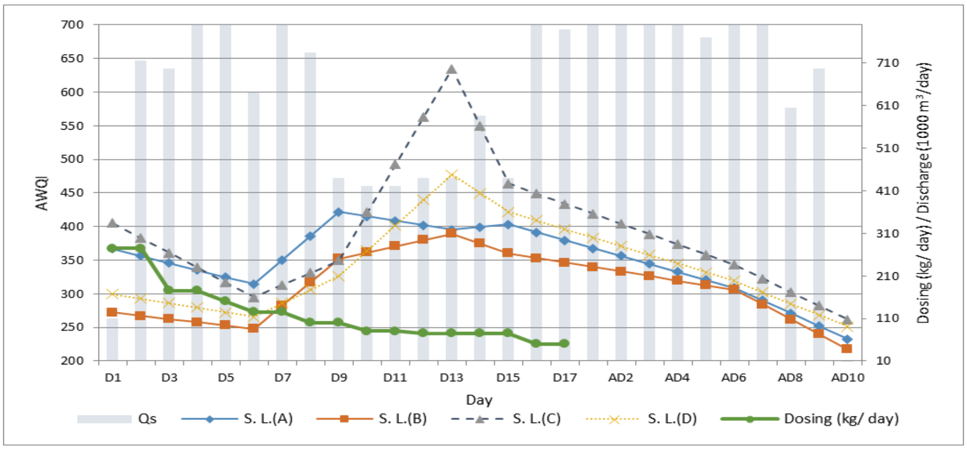


Figure 7: AWQI results for field test (High flow condition, study area "1")

Semi-structural interview

An interview with the farmers in the study area has been done. The purpose of such interviews was to investigate the impact of applying the bio-base material in water and detect the effect to the fish and plants and rather more to the odor. It was reported that a remarkable improvement in water transparency and odor have been improved.

Table 7: Dosing schedule

Day	Material added (kg/ day)	Ambient concentration mg/L
1 and 2	69*2	3
3 and 4	57.5*2	2.5
5 and 6	46*2	2
7 and 8	34.5*2	1.5
9 and 10	23*2	1
11 till 15	17.25*5	0.75

Q_{Ave} = 20,000 m^3/day

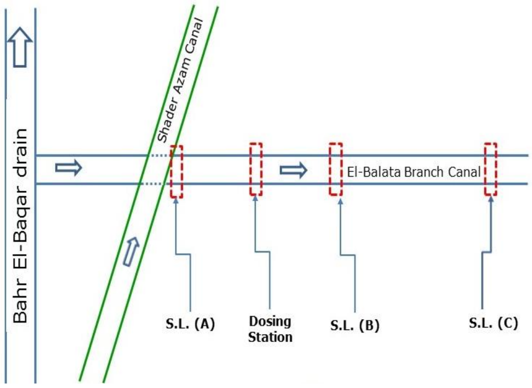
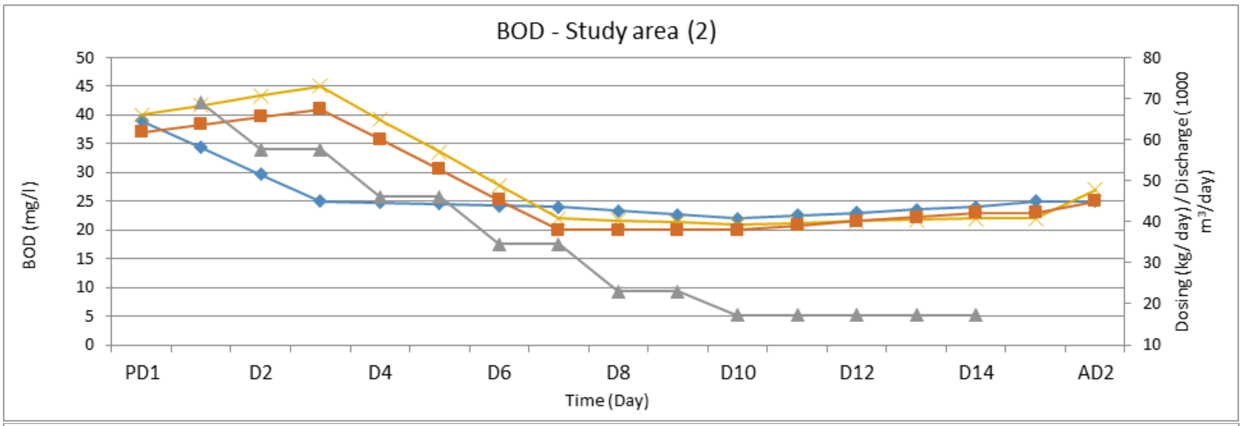
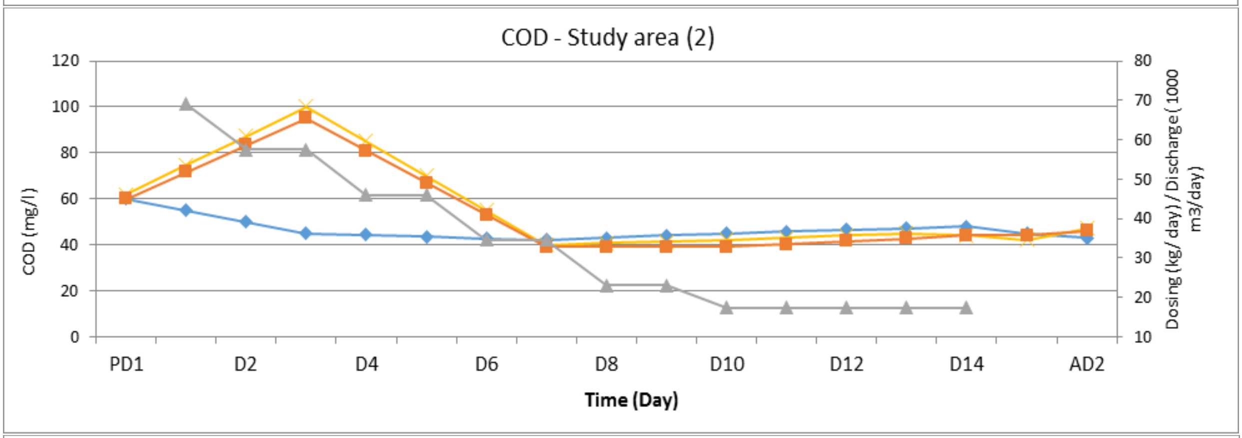


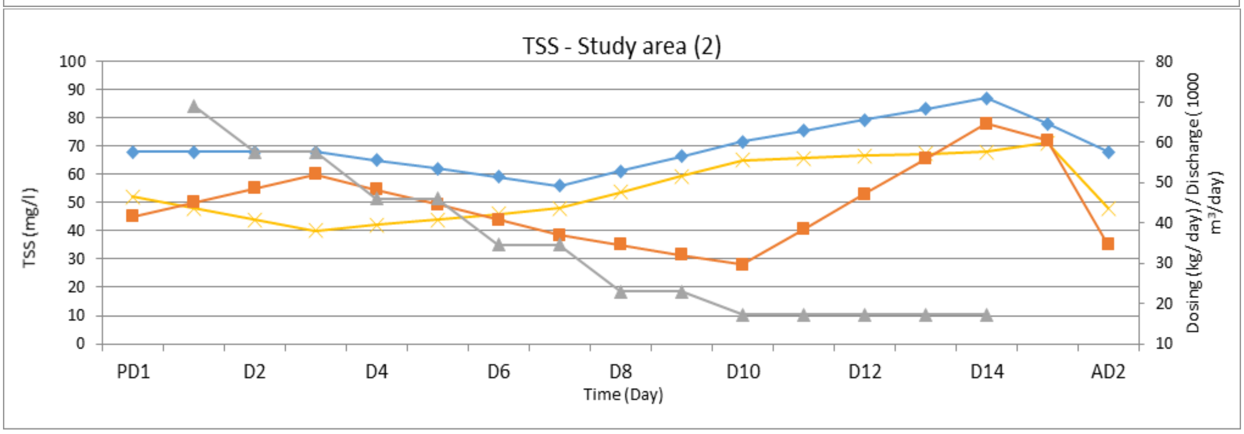
Figure 8: Grab samples locations (surface water and sediment) for Study area "2"

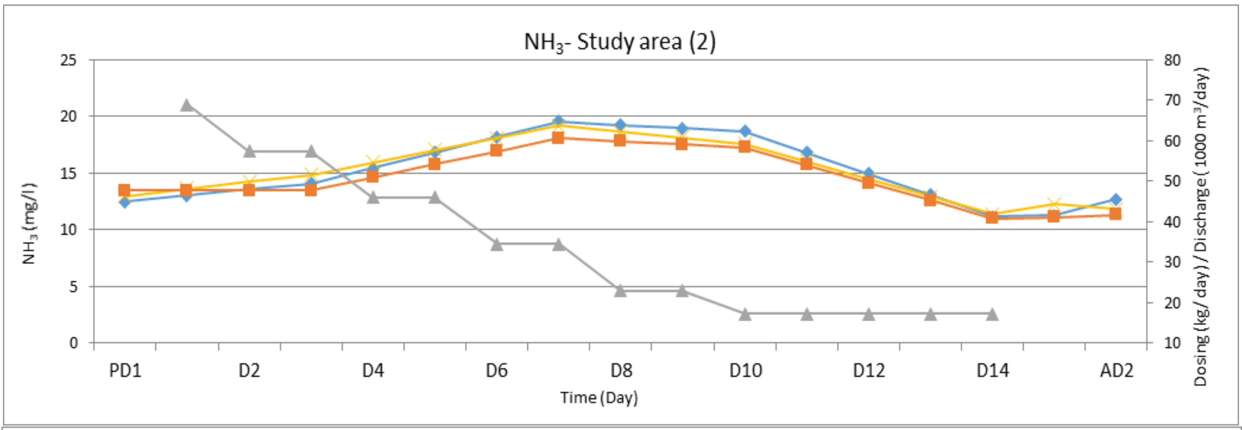
Table 8: Relative improvement in WQPs – study area "2"

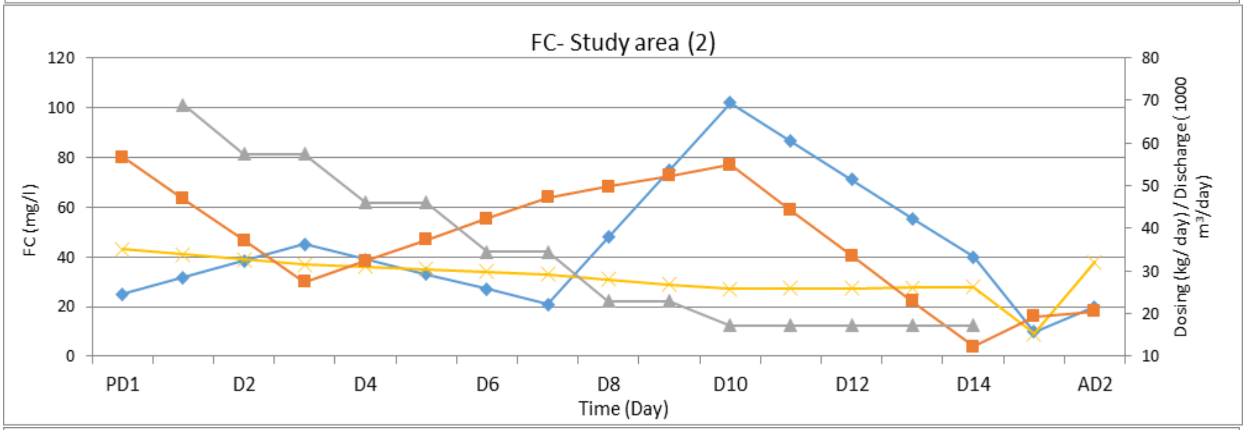
Parameter (WQP)	Max. Relative improvement S.L. (C)/ S. L. (A)	Max. Relative improvement S.L. (B)/ S. L. (A)
BOD	17% @ D7	8% @ D7
COD	13% @ D10	8% @ D14
DO	19% @ D10	7% @ D3
TSS	61% @ D10	35% @ D4
NH_3	8% @ D7, D8	6% @ D10
TP	7% @ D10	9% @ D14
FC	25% @ D10	18% @ D3
Oil & grease	39% @ D10	13% @ D3

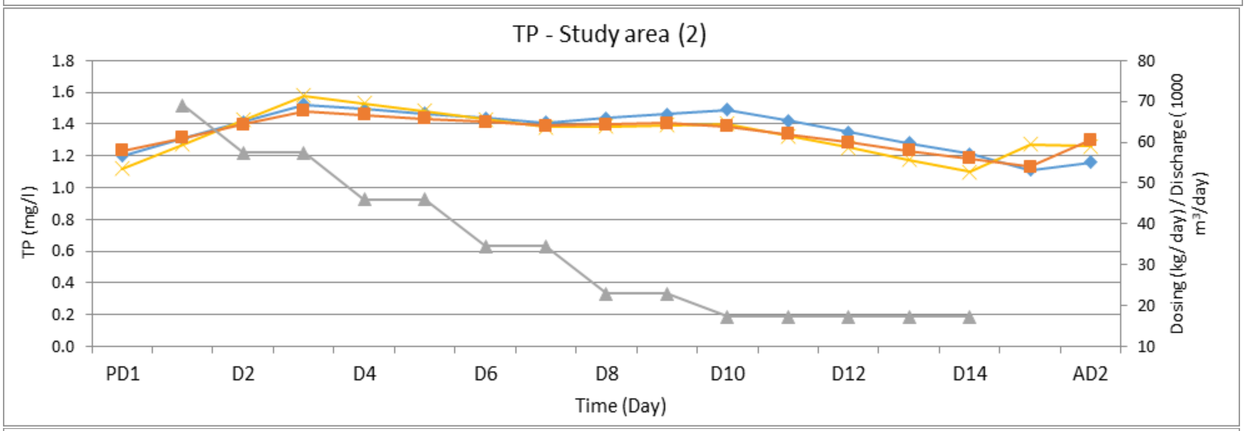


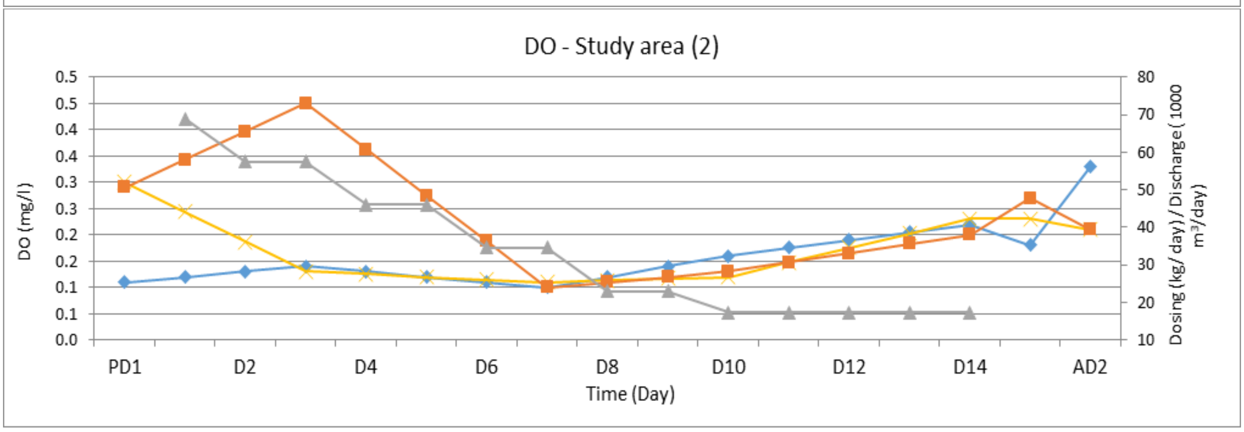





NH3- Study area (2)
NH3 (mg/l)
Dosing (kg/ day) / Discharge (1000 m3/day)
PD1 D2 D4 D6 D8 D10 D12 D14 AD2
Time (Day)


FC- Study area (2)
FC (mg/l)
Dosing (kg/ day) / Discharge (1000 m3/day)
PD1 D2 D4 D6 D8 D10 D12 D14 AD2
Time (Day)


TP - Study area (2)
TP (mg/l)
Dosing (kg/ day) / Discharge (1000 m3/day)
PD1 D2 D4 D6 D8 D10 D12 D14 AD2
Time (Day)


DO - Study area (2)
DO (mg/l)
Dosing (kg/ day) / Discharge (1000 m3/day)
PD1 D2 D4 D6 D8 D10 D12 D14 AD2
Time (Day)

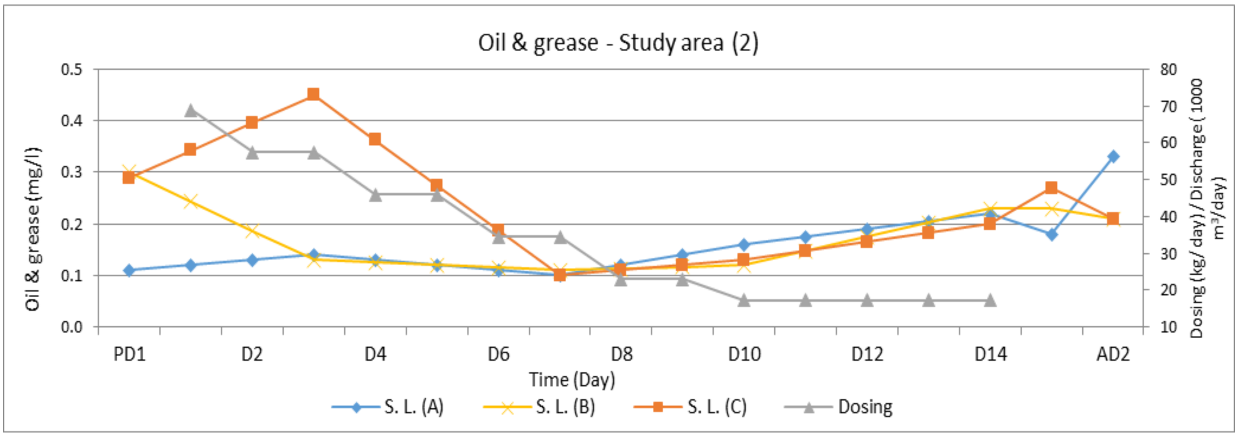


Figure 9: Measured values, percentage and overall improvement of selected WQPs (study area 2)

Table 9: Results of AWQI for Study area "2"

	AWQI															
	PD1	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	AD1	AD2
S. L. (A)	376	383	373	363	365	367	369	372	380	389	397	382	367	352	337	315	322
S. L. (B)	388	428	449	471	445	418	392	365	360	355	350	341	331	322	313	313	318
S. L. (C)	381	401	417	433	411	390	368	347	343	338	334	329	324	318	313	299	295
Dosing		69	58	58	46	46	35	35	23	23	17	17	17	17	17		
SP1/ SP3 improvement	-1%	-5%	-12%	-19%	-13%	-6%	0%	7%	10%	13%	16%	14%	12%	10%	7%	5%	8%

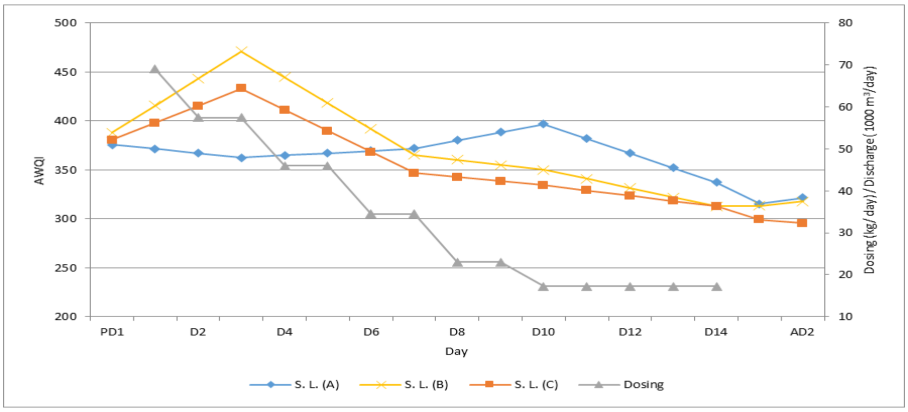


Figure 10: AWQI results for field test (Low flow condition, Study area "2"

V. CONCLUSIONS

Bench scale test

- The results values for individual selected parameters show high improvement in water quality (overall and relative improvement) as shown in (Figure 2, Table 2), where most maximum relative improvement values happened during the first 48 hours;
- The graph in figure3 shows high improvement in AWQI during the period of application of H24 to H168, varied from 22% to 26% respectively (difference in AWQI between CS & TS);
- Bench scale test proved the capability of bio-based material to clean polluted drainage water under laboratory conditions.

Study area "1": High flow condition with intermediate shock flow

- The results values for individual selected parameters show high improvement in individual water quality as shown in (Figure 6, Table 5), where most maximum results of parameters values happened around D6 and D13 to D16 during the period of chock flow;

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- The graph in figure 7 shows high improvement in relative water quality during the period of application varied from 1 to 26% in AWQI. This is resulting from both the application of compound and the dilution resulting from sudden shock flow;
- While it shows increase in the value of AWQI during the time of average discharge;
- The application of bio-based material can be limited by a maximum discharge of 500 thousand m^3/day to be cleaned by material in the open stream water systems and suitable retention time;
- The low retention time between inlet (Before treatment) and outlet (after treatment) measuring points limited the ability of the sampling program to capture the full benefit of the bio-based material, even so, the limited retention time was enough to allow slight enhancement in AWQI;
- The sudden shock flow that was pumped during application time (up to 900 thousand m^3/day), also disturbs the process of cleaning;
- The high discharge of drain 2 was both affected by the application of bio-based material in drain and dilution from the sudden shock flow in which, there was slightly effect on the water quality in drain 2.
- As overall conclusion for the application of bio-based material in study area "1": the effect of material was observed, but the dose rate should have been adjusted to match the change in discharge.

Study area "2": Low flow condition with intermediate shock pollution load

- The results values for individual selected parameters show high improvement in individual water quality as shown in (Figure 9, Table 8), where most maximum results of parameters values happened around D3 during the period of chock load and proved by AWQI;
- Figure 10 shows significant improvement in water quality during the period of application varied from "13%" to "16 %" as relative AWQI;
- The effect of applying material can easily be noticed in low flow discharge;
- It was clearly observed the improvement in odor and water transparency;

Further works

- Directing a further study to evaluate the efficiency when applying the bio-based material directly at PSPs (inefficient WWTPs, septic tanks, fish farming, etc.), which end-up with their effluent to water streams;

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