A DGPS-METHOD TO MEASURE SEDIMENT ACCUMULATION RATES IN WSPs. APPLICATION IN TUNISIA

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Abstract:
The accumulation of sediments is an important issue for the management of WSP systems. The accumulation rate of sediments in those systems has to be quantified in comparison with other WWT Plants , such as activated sludge. Appropriate sludge removal periods are crucial for WSP management, even if those events are not frequent. Thus data are needed in order to be able to decide when, how and in which quantity the accumulated deposits have to be removed. Moreover, it is well known that the net accumulation rate per capita will also depend on environmental conditions (climate, temperature, inlet mineral SS, etc.). Thus it is important to measure those accumulation rates in various ponds in the same country for better sediment management. We have developed a method based on 2 DGPS, linked together and connected to an echo sounder that can be placed on a small boat. In this way we could produce bathymetric maps of more than 4 ha in less than one day, with nearly one-centimetre accuracy. This can also help greatly to define sampling procedures. The method will also facilitate the identification of higher accumulation spots, and even to follow the compression effect.

Key words: sludge accumulation rate, wastewater stabilization ponds, sludge distribution, DGPS, echo sounding

INTRODUCTION
Usually WSP systems have several ponds in series. As there is usually no artificial mixing or aeration system in the ponds and the turbulence induced by usual winds is not strong enough to maintain all the solids in suspension, portions of the influent SS but also of the biomass (bacteria and algae) produced in the reactor will settle in the ponds (NELSON *et al.*, 2004). At the bottom various processes occur in those sediments: organic compound and nutrient exchanges with the overlying liquid phase, oxygen consumption in the upper layer (NAMECHE *et al*, 1997), compression and anaerobic processes, etc. The sediments also gradually reduce the active volume of the ponds and the shape of the bottom as well (PENA *et al.*, 2000), which may result in less efficiency (SCHNEITER *et al.*, 1984). Removal has to be organized periodically, but the period needs to be defined properly to avoid a huge increase in operating costs. Specific accumulation rates per capita have been suggested in the literature to help with those tasks (MARA *et al.*, 1992; OAKLEY, 1998)). The spatial distribution of deposits is usually uneven and related to the geometry of the ponds (FRANCI, 1999). It is thus important to get a map of the deposits, as depth has frequently been observed to vary (SCHNEITER *et al.*, 1984; CARRE *et al.*, 1990; NELSON *et al.*, 2004). Frequently most of the sediments accumulate near the ponds’ inlets and outlets (NARASIAH *et al.*, 1989; LEGEAS *et al.*, 1992; SCHETRITE and RACAULT,1995; NAMECHE *et al.*, 1997). Explanations have been proposed by MIDDLEBROOKS *et al.* (1982), HAMMOU *et al.*, (1992) and BILHALVA *et al.* (2004).

Studies have described the accumulation rates expressed as cm/year (usually in the range of 1 to 5: HAMMOU *et al*.(1992), NELSON *et al*.,(2004), ITO (2001), BARON *et al.* (1987)) or as m^3/year per capita (in the range of 0.02 to 0.06: GOMES DE SOUSA (1998), PICOT *et al.* (2003), NELSON *et al.*,(2004)) or better as kg SS /year and per capita. However, this last figure is more difficult to obtain and thus rarely provided. As the deposits may have a very uneven spatial distribution, a careful sampling procedure has to be defined to get accurate average values for the ponds. Moreover PICOT *et al* (2005) have demonstrated that due to the slow reaction rates of anaerobic processes, the volume of deposits decreases slowly with time, so it is also important to know the age of the pond to analyse the results.

In most cases the depth of the deposit is measured manually by the pole method. A grid is drawn for the pond and measurements are located on the grid to facilitate maps. Examples can be found in KEFFALA *et al.* (2008). When the grid's cell size is small, the amount of work becomes tremendous. In this paper we describe a new method based on two DGPS receivers linked to an echo sounder that can greatly facilitate the task.

MATERIALS AND METHODS

Fig 1. Reference station: calculation of error and link by radio modem

Fig 2. Rover in portable configuration, embankment (topographic survey)

Fig 3. Echo sounding at El Jem: system configuration. The GPS antenna is clearly visible

Fig 4. Rover in echo sounding configuration on Gammarth's first basin

In order to solve the time-consuming problem of manual measurement we decided to set up a DGPS system that would yield a precision of approximately 1cm. The system is composed of two GPS receivers (Leica system 1200 and antenna AX 1202 GG): The first one, located on a defined point selected to find many satellites signals, is used to calculate errors, and the second is moved around the pond to measure the area directly (topographic measure of the embankment). The two GPSs communicate by radio modem (RTK Real Time Kinematic configuration) (Fig.1, 2 and 5). In the next step the second DGPS (rover) is placed on a small boat (see Fig. 3) with the antenna placed at a fixed distance from the water's surface. The boat then moves across the pond, at a speed of approximately 10 km/hr (Fig. 4). The boatman tries to follow approximately a predefined grid (every 5 m in our case), with someone providing information from the embankment. An echo sounder (Tritech Model PA 500) is also located on the boat. Dedicated software has been developed in the lab to communicate directly between the DGPS and the echo sounder. The echo sounder measures the depth (Z) of the sediment at given time intervals (1 sec). It simultaneously sends a signal to the DGPS, which will calculate the other coordinates (X,Y) of the point. Data are stored in the system 1200's mass storage. The advantage of the DGPS technique is therefore theoretically better accuracy, with the high number of points, and a definitely much higher speed.

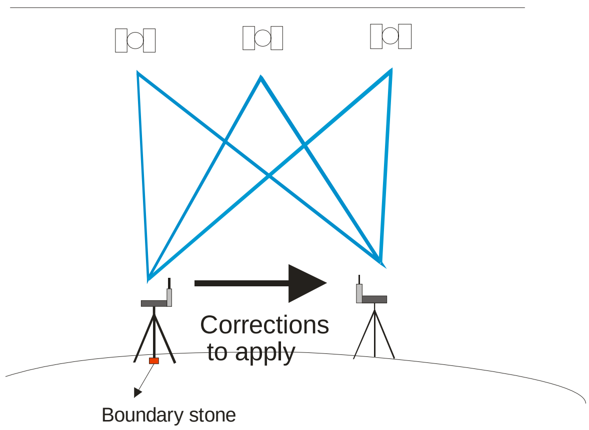


Fig 5. Principle of DGPS measurements

RESULTS AND DISCUSSION

Some typical results are shown in Fig. 6. We shall follow this with a complete example of this file's processing, and after that we shall give the results for the other treatment plants. Here are the main characteristics of the two treatment plants studied:

Table 1. Main characteristics of the pond studied

Treatment plant	Since	Type of lagoon	Nominal hydraulic load m^3/d	Nominal load (kgBOD/d)	Actual conditions (m^3/d)	Actual conditions (kgBOD/d)	Number of PE	Volume m^3	Surface area m^2
Gammarth lag2	1981	(Aerated) facultative	7875	2500	8200	2732.5	50602	609157	222320
El-Jem	1994	natural	1250	600	1027	440	8148	9592	9404

Case of Gammarth

First we collected the spatial data in Leica Geooffice®. We can clearly see the trajectories of the boat. This represents more or less 5500 data points for a 450 m x 450 m basin.

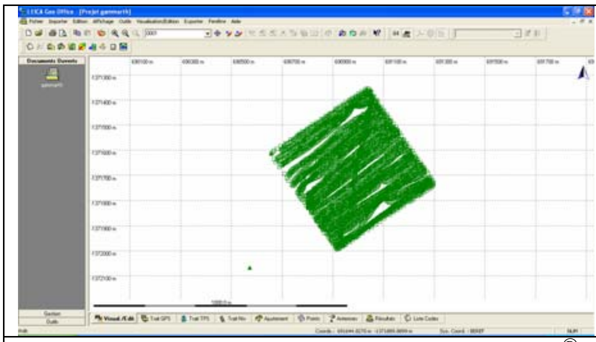


Fig 6a. The data points in Leica Geooffice®.

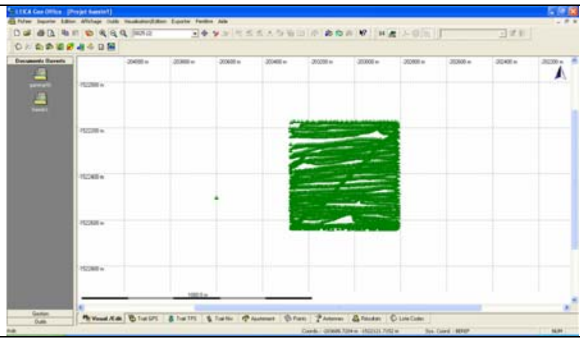


Fig 6b. Rotation of the data points in Leica Geooffice®.

To obtain better accuracy, we applied a 3D transformation to represent the basin horizontally or vertically, then exported the points to the Surfer software (Surfer 8.01 Golden Software ®). This software allows interpolation by kriging (*Kriging* is a geostatistical gridding method that has proven useful and popular in many fields. This method produces visually appealing maps from irregularly spaced data.), yielding a final matrix of 474 rows x 471 columns, thus 223 254 data points. And finally, we obtained the graph presented in Fig. 7, illustrating the positions of sediments in the basin. On this graph we can also identify the old feeding systems (6 deeper zones) of the basin and the positions of surface aerators. The inlet of the basin is now in the upper left corner.

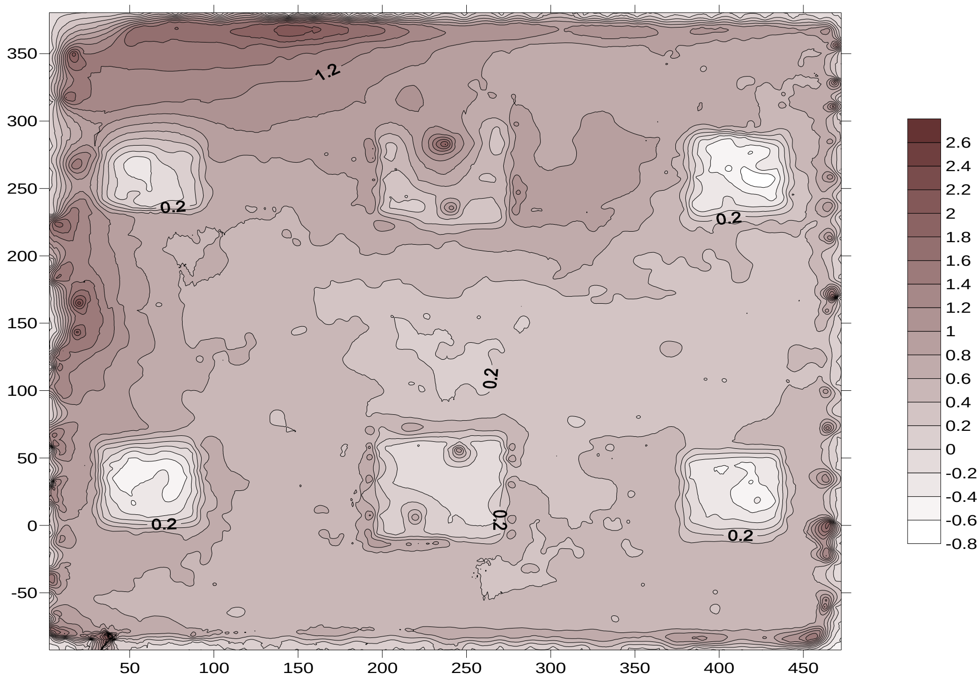


Fig 7. Map of Gammarth basin N°2; distance between isolines is 0.2 m

We can also show a stereoscopic representation in the following graph:

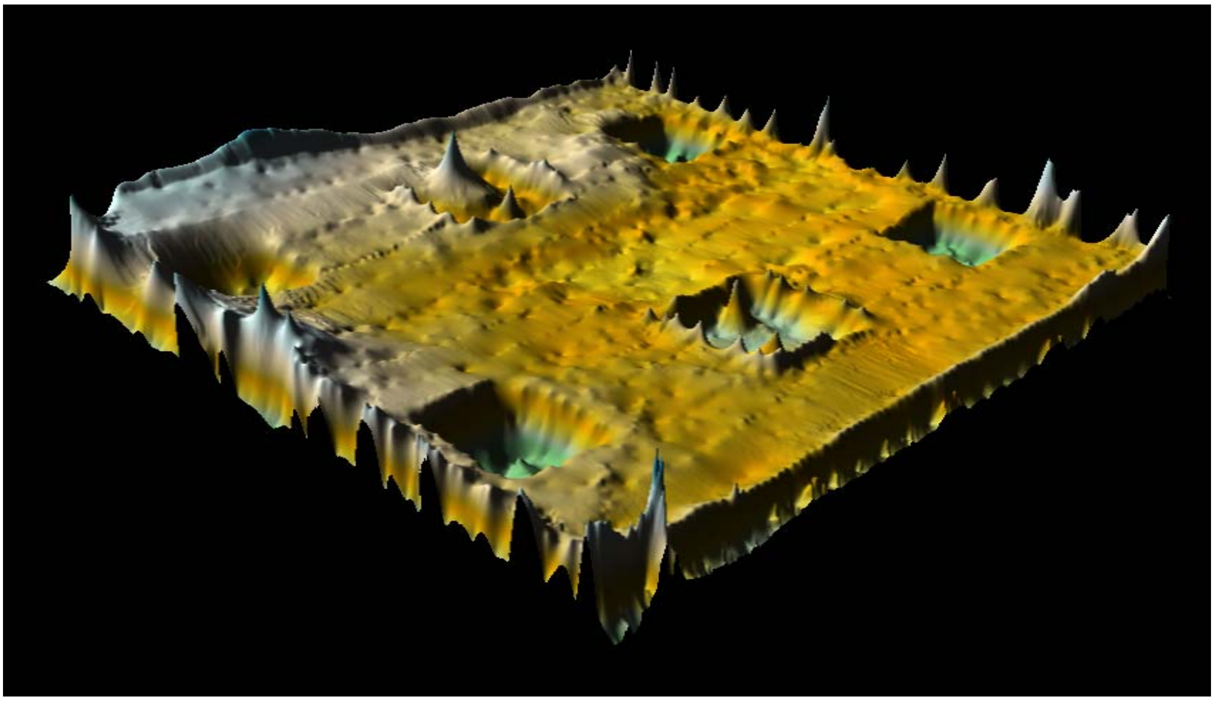
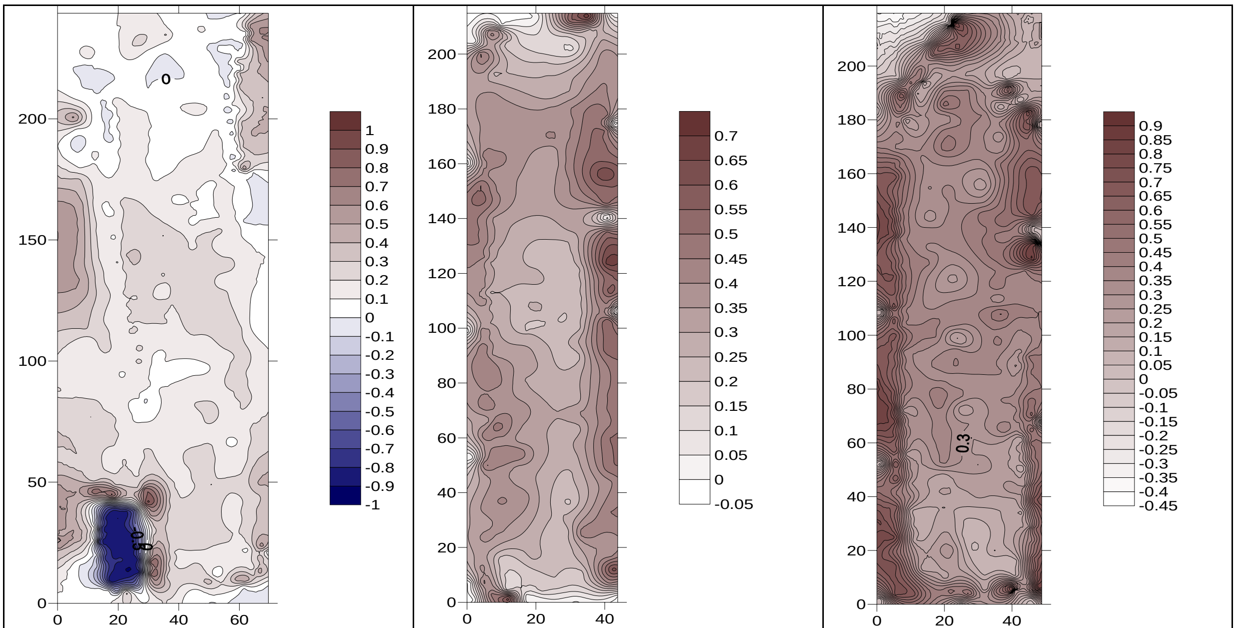


Fig 8. Stereoscopic map of Gammarth Basin 2

This 3D representation (Fig. 8) offers a better point of view, for we can clearly see the accumulation at the basin’s inlet. Finally, we can calculate the sediment volume in the basin from these graphs by simple integration (Simpson or trapezoidal method) with a boundary horizontal section at the bottom of the basin. In our case the integration leads to a volume of 122 905 m^3 of deposits over an area of 22 ha, for an average deposit level of 55 cm.

Figure 9 presents the results obtained at the El Jem treatment plant. This WSP system has three basins in series.



Depths of deposits in Basin 1	Depths of deposits in Basin 2	Depths of deposits in Basin 3

Fig. 9. Iso-depth values for the El Jem Pond system (Equidistances are expressed in m)

Finally, we calculated the following values:

Table 2. Results of sediment measurements in two WSP systems in Tunisia

Basin	Volume of sediments m^3	Pond area m^2	Pond depth m	Average deposit m	Max deposit level m	Accumulation rate l/PE.year
Gammarth B2	122905	222320	2.74	0.55	2.52	93
El Jem B1	2608	16953	1.3	0.15	0.92	25
El Jem B2	3034	9404	1.02	0.32	0.68	29
El Jem B3	3787	10731	1.17	0.35	0.86	36
Total for El Jem	9429	37088				89

CONCLUSIONS

The methodology presented has proven to be much faster than the traditional technique. For example, the Gammarth second aerated pond (22 ha) was measured with 5500 data points in only one day, including the time needed for determining the embankment's topography. The three ponds of El Jem were also measured in less than one day.

The precision is better than that of the traditional technique, for two reasons:

- The XYZ position error is centimetric. It is impossible to obtain this degree of precision with a ten metre-yardstick on a large basin. Proof of this can be obtained from the boat's trajectories. Despite signalling, the boat's pilot cannot avoid deviations. The DGPS system records the true position and this position is used in the kriging method of extrapolation.
- The number of recorded points is very high, so the extrapolation is more precise. Moreover the monitoring steps are numeric and automatic, which avoids transcription errors.

The values calculated for Gammarth Pond No. 2, which is an aerated lagoon, and the whole El Jem treatment plant are in the range found in the literature (40-100 l/PE.year) (KEFFALA *et al*, 2008). The HRTs for El Jem and Gammarth are 9 and 74 days, respectively, and the organic loads ($gBOD/m^2.d$) are respectively 47 and 12. These differences can explain the difference in accumulation, but the latter is due mainly to the basin's configurations. In the case of Gammath, we can reasonably suppose most of the accumulation takes place in the first lagoons, which yield values in the literature range. Moreover, a total of 15000 m^3 of sediments was extracted in 2007 and 2008, with a large fraction of sand. In the case of El Jem, sediments were also extracted from the first pond, but we do not currently know the exact volume.

In a future paper we shall compare the RTK method of DGPS with a post-treatment method requiring a cheaper investment.

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